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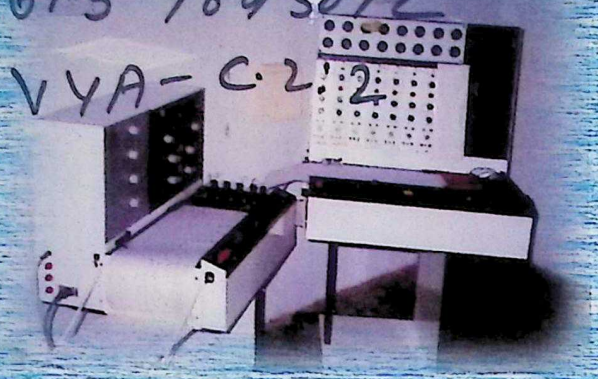

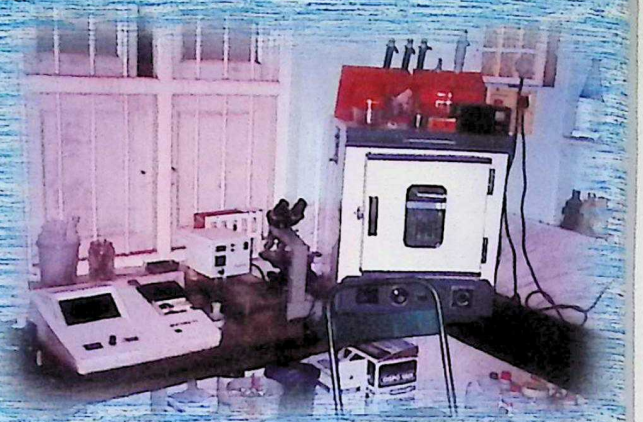

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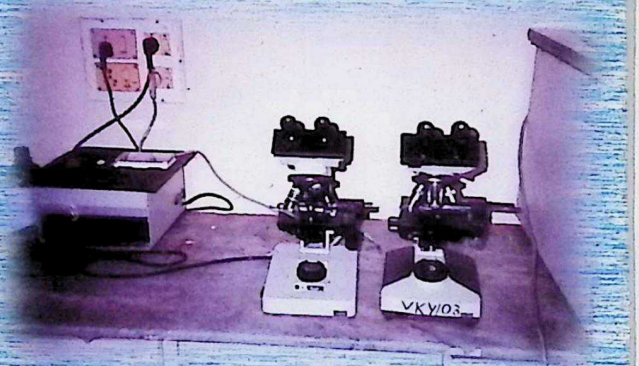

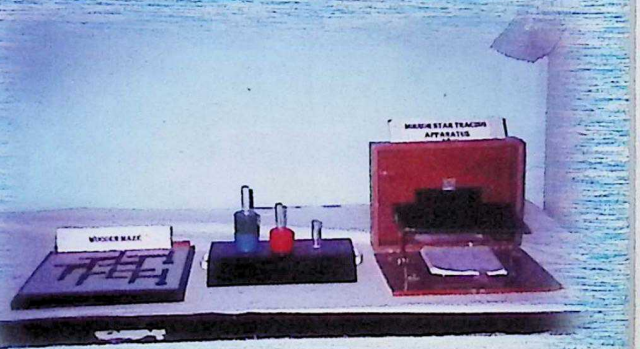

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Vivekananda Yoga Anusandhana Samsthana

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Volume II : Psycho Physiology of Yoga and Rehabilitation

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"Research Contributions of VYASA" comprising 59 articles is a reference book for scientists. professionals, yoga researchers and practitioners. It includes 56 articles published in International and National (indexed and non-indexed) journals and 4 articles as chapters in books. All these publications are based on the research work done by the "Research Team" of this institution since 1982.

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PREFACE

The work started way back in 1977 in Kanyakumari to unravel the hidden secrets of Yoga by systematic internal research and literature search. The central question was "Can Yoga be useful to solve the challenges of our society such as stress, psychosomatic ailments, social disharmony, student unreset, family divorces, increasing gun culture, terrorism, drug culture and so on?" Initially we took up Yoga as a therapeutic tool and for stress relief.

After going round the country visiting various Yoga institutions, meeting famouns Yoga masters, we came back to set out suitable modules of Yoga practices for different ailments. We combined the latest research knowlede base available in modern medicine with the principles and practices of Yoga. The result was the emergence of the Integrated Approach of Yoga Therapy (IAYT); the basis was culled out from Taittireya Upanisat and Yoga Vasistha. This paper was first published in Yoga Review in 1984, which was our first scientific publication. We started using this IAYT in the treatment of various categories of diseases such as asthma, diabeted, hypertension, etc. Systematic documentation of measurements made on the patients before and after Yoga and the later long term follow up, brought out highly significant improvement in the health status. These clinical trials were published and our first major publications was the one in British Medical Journal and Yoga for Bronchial Asthma. And the next was in Journal of Asthma in USA. Since then we have never looked back. More and more researchers were drawn, the research team started functioning with zear, enthusiasm and commitment to examine the usefulness of Yoga in stress management, Yoga in Education, Yoga for development of eyesight, memory, IQ, perception, stamina, creativity, etc. We also started research to understand the physiological and psychological aspects of various Yoga practices - the basis research initiated by swami Kuvalayananda in the 40's and 50's. The effect on the nervous system were studied by measuring autonomic functions through polygraphs in our neurophysiology lab. Soon we started our investigations using experimental psychology lab to unravel the effect of Yoga on various dimentions of the brain capacities. In all these investigations there were such positive results that our enthusiasm and faith increased to take up more exacting research, needing more funds.

Understanding the mechanisms involved in the causation of diseases at physiological, biochemical, immunological and psychological levels was our next launch, which continues even now.

We also took up research to understand and unravel the subtler, unseen dimentions of Yoga. The question was, "Can we recognise and photograph pranic body? Can we measure prana? Can we track the mind, its manifestations at the brain funcitoning level? Can we differntiate mind with intellect and emotions? Can we bring the philosophical studies of consciousness into more consciousness into more concrete terms?", and so on and on. Our search has expanded into alternate year in our headquarters - a science campus named Prashanti Kutiram. The provision for doing Ph.D. in Yoga and ailled sciences gave a quantum jumb into our research after we go the recognition form Bangalore adn Mysore Universities.

We compiled the titles of all our research publications in compendium entitled "Research Contributions of sVYASA". The two conference proceedings, which have been brought out. give the full papers published in these conference.

The present publication is a compilatino of all our important research papers published in indexed and non indexed national and international journals, conference proceedings (not our own conference proceedings) and as chapters in books.

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The papers have been arranged in the following sequence -

1. Physiology of Meditation Techniques
2. Physiology of Pranayama
3. Therapeutic applications of Yoga
4. Yoga for rehabilition and
5. Yoga in perception and performence

The purpose of bringing out this research compilation in not commercial. There has been a request for reprints for all our publications by genuine research round the globe and hence the need was felt for bringing out this compilation. This compilation of 55 reserach papers and the four articles as chapters in books, we hope will be of great use to the medical professionals and other scientists to take up more and more research in yoga and its applications.

We thank all persons who have helped in bringing out this publication of VYASA

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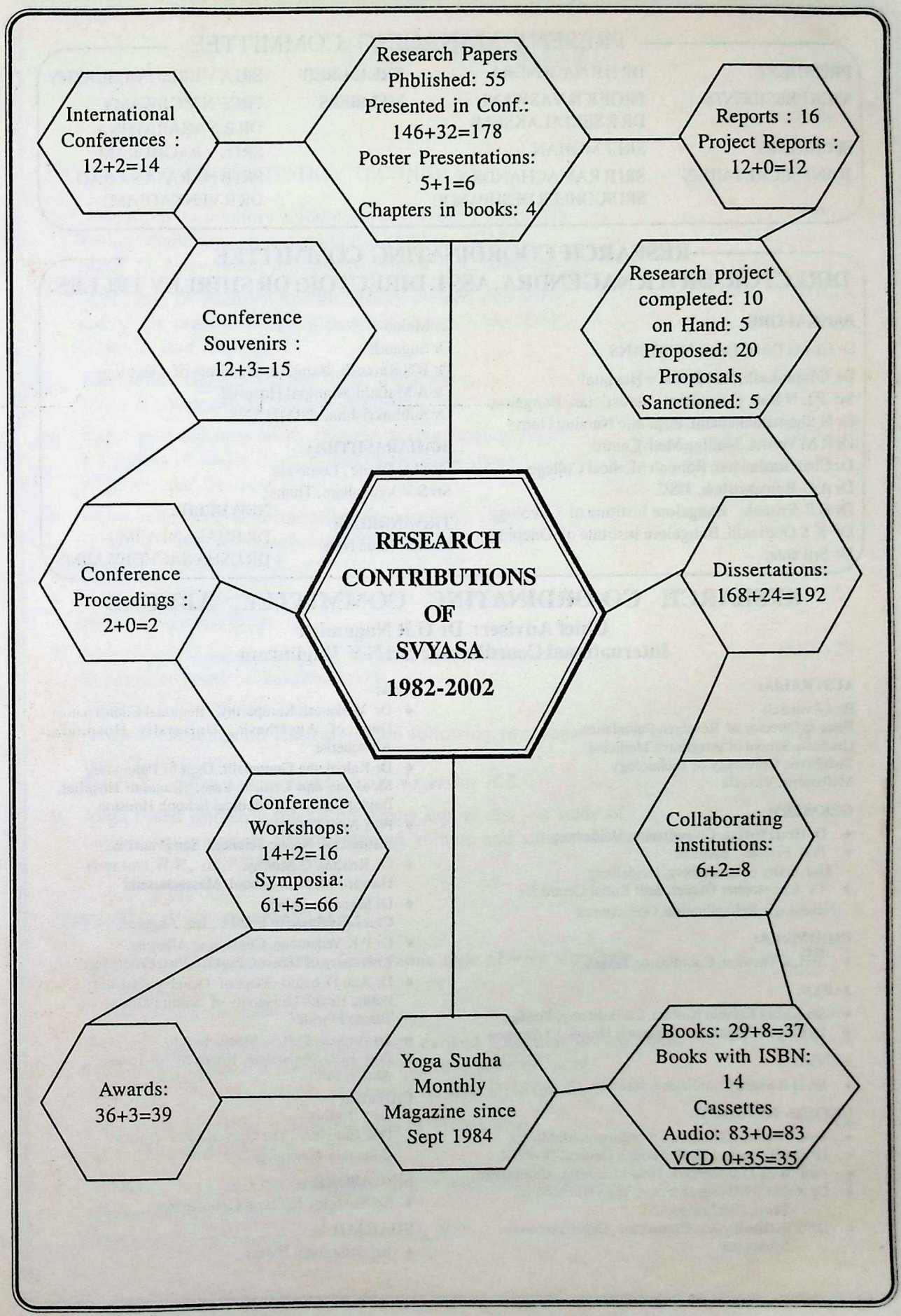

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PHYSIOLOGY OF MEDITATION

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Intern. J. Neuroscience. 1994. Vol. 76, pp. 87-93.

ALTERATIONS IN AUDITORY MIDDLE LATENCY EVOKED POTENTIALS DURING MEDITATION ON A MEANINGFUL SYMBOL - "OM"

Shirley Telles, Nagarathna S., Nagendra H.R., and Desiraju T.

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(Received September 15, 1993)

Middle latency auditory evoked potentials were recorded in 18 male volunteers with ages between 25 and 45 years, 9 of whom had more than ten years of experience in "Om" meditation (senior subjects), whereas the other 9 had no meditation experience (naive subjects). Both groups were studied in two types of sessions. (1) Before, during, and after 20 minutes of mentally repeating "one" (control session), and (2) a similar session, though with 20 minutes of mentally chanting "Om" (meditation session). The senior subjects showed a statistically significant (paired t-test) increase in the peak amplitude of Na wave (the maximum negative peak between 14 and 18 ms) during meditation, while the same subjects showed a statistically significant reduction in the Na wave peak amplitude during control sessions. In contrast, the naive subjects had a significant decrease in the Na wave peak amplitude during meditation sessions and a nonsignificant trend of reduction during control sessions, as well. This difference between senior and naive subjects was significant (two way ANOVA). There were no significant changes in short latency wave V or Pa wave (the positive peak between the Na wave and 35 ms). The changes in the Na wave suggest that both meditation on a meaningful symbol, and mental repetition of a neutral word cause neural changes at the same level (possibly diencephalic). However, the change could be in opposite directions, and this difference could be correlated with differences in the duration of experience in meditation between senior and naive subjects.

Key words: *Middle latency auditory evoked potentials; Meditation-Meaningful symbol- Neutral word.*

Meditation has been described as a training in awareness which, over long periods, produces definite changes in perception, attention and cognition (Brown, 1977). Objective evidence of such altered sensory perception exists, since yogis in deep meditation showed an absence of alpha blocking in the EEG even when exposed to diverse (visual, vibratory. thermal, and sensory) stimuli (Anand & Chhina, 1961).

The effects of Transcendental Meditation (TM) on auditory evoked potentials (AEPs) have already been reported. The first study (Barwood, Empson, Lister & Tilley, 1978) showed that long latency AEPs (i.e., with latency more than 100 ms) did not change significantly during meditation. Later on, McEvoy, Frumkin and Harkins(1980), reported a change in short latency (brainstem) AEPs after meditation. Hence, if short latency AEPs change, whereas long latency AEPs remain unaltered during meditation, the effects of meditation on middle latency AEPs is interesting. This knowledge could help in understanding how neural processing at different stages alters with meditation.

Hence the present study was carried out, recording middle latency AEPs during meditation on the syllable. "Om", which has profound significance in Indian belief. Recordings were made at the end of a 10 day retreat during which subjects meditated for approximately 6 hours a day, and maintained silence for the remaining time.

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METHOD

Subjects

There were two groups of nine subjects each. They were all males, with ages ranging from 25 to 45 years. The first group (average age 32.1 ± 4.2 years) consisted of "Senior subjects" who had more then 10 years experience in meditation (average 12.4 ± 1.8 years). The second group (average age 36.2 ± 3.8 years) cosisted of "naive' subjects who were strongly motivated to practice mediation, but had no experience prior to the present, intensive 10 day retreat. The study was explained to the subjects. and their signed informed consent was taken, according to the ethical guidelines of the Indian Council of Medical Research (New Delhi, India)

Sessions

All the subjects were studied in 2 types of sessions, each lasting 32 min. (a) The "control" or nonmeditation session consisted of 20 min. of sitting with eyes closed, mentally repeating a neutral word i.e. "one". This period was preceded and followed by two 6 min. periods of sitting relaxed, with eyes closed. The next session was recorded after a gap of about 15 minutes during which the electrodes were disconnected, and the subjects were allowed to get up.

This next session (b), was a meditation or "test" session, which was identical in design to the control session described above, except the 20 min. spent repeating "one," were spent mentally chanting the syllable "Om".

Meditation

Indian teachings consider the syllable "Om" to be the force behind all thought. Either uttering or thinking about "Om" is supposed to cause a quiet mental state. The meditation practiced in the present study involves mentally chanting the syllable "Om."

Recording of Evoked Potential

Middle latency auditory evoked potentials (AEP-MLRs) were recorded in the 70ms poststimulus time period, from Cz, referenced to the left earlobe, with the ground electrode on the forehead. The preamplifier band width was set at 1-1500 Hz. 1500 responses were averaged for each period. Sweeps containing artifactually large signals were rejected through software specification. The rejection level was expressed as a percentage of the full scale range of analog-to-digital convertor. This level was set at 100%. The number of sweeps was also known from the print-out (NICOLET, USA. Clinical averaging package). Click stimuli of 40 μs duration and alternating polarity were delivered at 5 Hz binaurally, through acoustically shielded earphones (Amplivox, UK). The intensity was kept at one and half times the threshold of hearing. This value was (on an average) 45 dB above the threshold of hearing, which was approximately 24 dB with stimulus parameters kept as described above. This was sufficient to evoke the potentials consistently, at the same time leaving the subjects undisturbed.

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TABLE 1

Peak Latencies and Peak Amplitudes of AEP - MLRs Recorded on Senior Subjects in Meditation (M) and Non-Meditation (NM) Sessions

		Wave V[a]		Na Wave[a]		Pa Wave[a]	
		M	NM	M	NM	M	NM
Peak Latency (ms)	Pre	6.8 ± 1.0	6.5 ± 1.2	16.3 ± 2.2	16.2 ± 1.9	28.4 ± 4.7	26.6 ± 4.1
	During	6.8 ± 0.9	6.5 ± 0.8	16.6 ± 1.8	16.7 ± 2.1	29.0 ± 4.4	28.7 ± 5.8
	Post	6.6 ± 1.0	6.7 ± 1.2	16.6 ± 1.8	16.1 ± 1.2	30.1 ± 4.0	29.6 ± 3.9
Peak Amplitude (uv)	Pre	0.7 ± 0.3	0.6 ± 0.2	1.0 ± 1.0	1.1 ± 1.4	1.3 ± 0.8	1.7 ± 1.4
	During	0.6 ± 0.2	0.6 ± 0.2	1.5[b c] ± 1.1	0.8[d] ± 1.1	1.3 ± 0.7	1.3 ± 0.7
	Post	0.5 ± 0.2	0.6 ± 0.4	1.3 ± 1.1	1.0 ± 0.9	1.1 ± 0.9	1.3 ± 0.9

[a] *N = 9*
[b] *$p < .05$, t-test for paired data, during to pre.*
[c] *$p < .05$, t-test for paired data, during M to during NM*
[d] *$p < .001$, t-test for paired data, during to pre*

AEP-MLRs Components

Peak amplitudes of short latency wave V, and middle latency Na and Pa waves were measured from the baseline existing at the beginning of sweep. Peak latency was measured from the time of click delivery.

The middle latency auditory evoked response components (AEP-MLRs) were described as follows: wave V was the maximum positive peak between 5 and 8 ms, the Na wave was the maximum negative peak between 14 and 18 ms, and Pa wave was described as the maximum positive peak between the Na wave and 35 ms. These descriptions are similar to those in other studies on AEP-MLRs (Erwin & Buchwald, 1986).

Data Analysis

The data were analyzed in two ways, viz a) using a two factor ANOVA (Factor A= senior subjects versus naive subjects and Factor B = Premeditation versus during meditation). The two factor ANOVA was repeated using the values obtained in control sessions as follows: Factor A= Senior subjects versus naive subjects and Factor B = Precontrol versus during control period. The t-test for paired data (two tailed) was used to check for statistical significance in the following comparisons: (1) premeditation with meditation, (2) Precontrol with control period, (3) meditation with control period.

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These two tests were carried out on the peak latencies and peak amplitudes of short latency wave V and middle latency Na and Pa waves.

RESULTS

The two factor ANOVA revealed a significant difference in the peak amplitude of the Na wave during the meditation session, between the two categories of subjects:

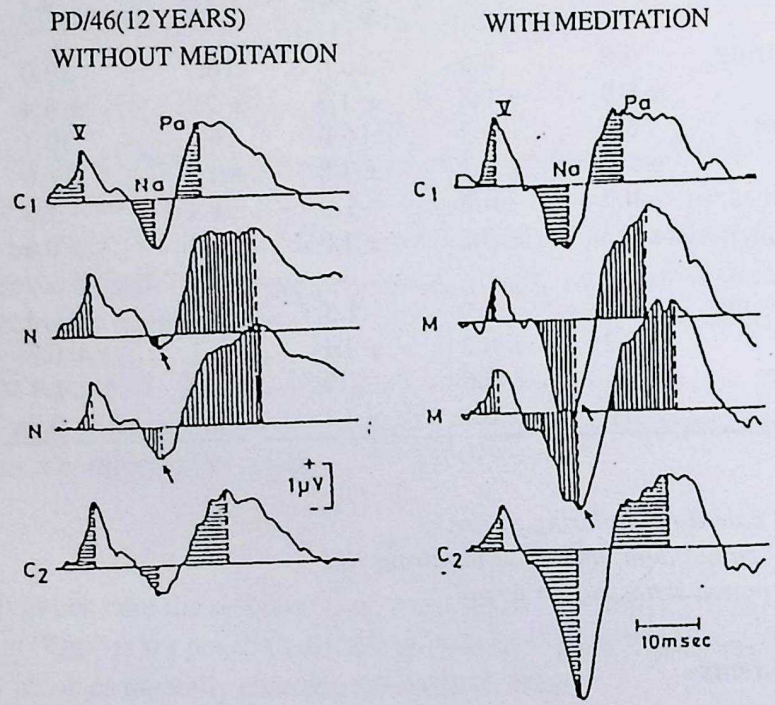

FIGURE 1 Typical example of AEP- MLRs recorded in a senior subject during a control session (left) and during a meditation session (right). IN each session AEP- MLRs were recorded four times i.e. before (C1), after (C2) and twice during a test period which involved either mentally repeating "one" (N of the control session). or meditation on "OM" (M of the meditation session).

(viz Factor A = seniors Vs naive subjects), [F = 4.60 (F .05 (1) 1, 32 = 4.15) hence p < .05] However, there was no significant difference between the two states (viz Factor B = premeditation versus during meditation), or of interaction between Factors A and B in meditation sessions (P > .10 in both cases). The two factor ANOVA for the peak amplitude of the Na wave during control sessions, and also for the peak latency and peak amplitude of the short latency wave V and the Pa wave, did not reveal significance of either factors or their interaction, during both meditation and control sessions (p > .10, in all cases cited above).

The t-test for paired data (two tailed), revealed a significant (t = 2.78, P < .05) increase in the Na wave peak amplitude of the senior subjects during meditation compared to the values of the preceding state, as well as compared to those of the nonmeditation (control) sessions (t = 2.69. p < .05). In contrast, there was a significant (t = 5.37, p < .001) reduction in Na wave peak amplitude during tile control period (while repeating "one") compared to the preceding state (Figure 1).

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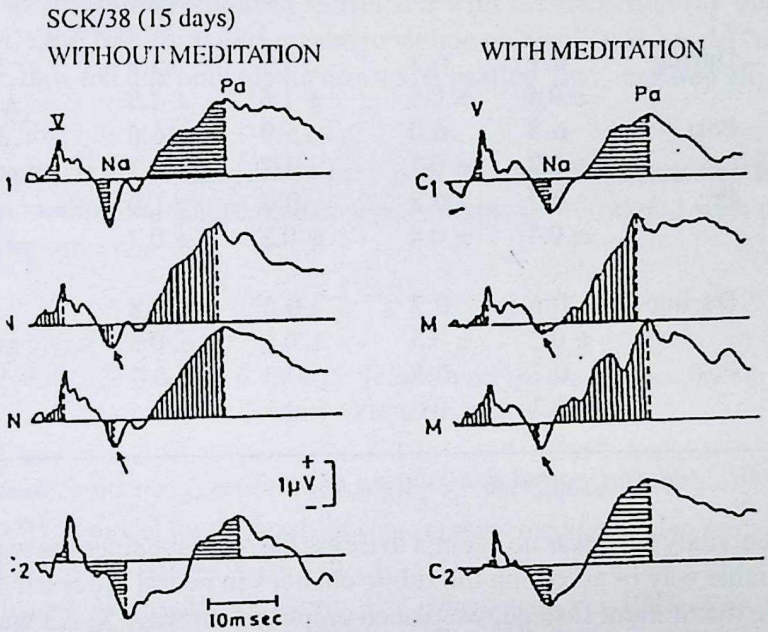
In the naive subjects there was a significant reduction in the Na wave peak amplitude during meditation sessions ($t = 6.16$. $p < .001$) compared to the preceding period (Figure 2). There were no significant differences in the Na wave peak amplitude of naive subjects during the control period compared to the preceding period ($p > .10$). Also there were no significant differences in the peak amplitudes and peak latencies of wave V and Pa wave, during both meditation and control periods, compared to their preceding periods or in a comparison between meditation and control periods for both categories of subjects ($p > .20$, in all comparisons)

AEP - MLRs DURING OM MEDITATION



FICURE 2 Typical example of AEP - MLRs recorded in a naïve subject during a control session (left). and during a meditation session (right). The rest of the details are the same as for FIGURE 1.

The group means and standard deviations of the different parameters for the senior subjects have been provided in Table 1, and for naive subjects in Table 2.

DISCUSSION

The results of the present study revealed that in subjects with more than 10 years of meditation experience there was a significant increase in the peak amplitude of the Na wave during meditation (mental chanting of "Om") compared to a significant decrease in the Na wave peak amplitude during a control period, spent mentally repeating "one." In contrast, naive subjects had a significant reduction in Na wave peak amplitude during meditation, and a nonsignificant trend of reduction during the control period, as well.

Our earlier study (Telles & Desiraju, 1993) on 7 subjects with meditation experience ranging from 5 to 25 years, showed that mentally chanting "Om" produces a small but consistent reduction in the peak latency of the Nb wave. However, this negative component shows considerable variability, and occurs between 35 and 65 ms, and hence it was mentioned that the change had to be viewed caution. It was also reported that changes in Na and Pa waves were fewer and often and often in opposite directions for different subjects, through there was less intersubject variability in the values.

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TABLE 2

Peak Latencies and Peak Amplitudes of AEP - MLRs Recorded on Naive Subjects in Meditation (M) and Non - Meditation (NM) Sessions

		Wave V[a]		Na Wave[a]		Pa Wave[a]	
		M	NM	M	NM	M	NM
Peak Latency (ms)	Pre	6.7 ± 0.8	6.3 ± 0.4	15.9 ± 1.6	15.0 ± 1.6	30.3 ± 4.1	28.5 ± 3.3
	During	6.1 ± 0.4	6.3 ± 0.5	15.3 ± 1.6	15.8 ± 1.9	29.6 ± 2.7	29.8 ± 2.1
	Post	6.5 ± 0.7	6.0 ± 0.7	15.9 ± 1.7	16.6 ± 2.7	30.1 ± 3.7	29.6 ± 3.5
Peak Amplitude (uv)	Pre	0.7 ± 0.4	0.8 ± 0.4	0.8 ± 0.3	1.0 ± 0.7	1.3 ± 0.6	1.6 ± 0.3
	During	0.6 ± 0.3	0.7 ± 0.3	0.5[b] ± 0.3	0.8 ± 0.5	1.4 ± 0.6	1.2 ± 0.5
	Post	0.7 ± 0.3	0.8 ± 0.6	0.9 ± 0.3	0.7 ± 0.4	1.3 ± 0.3	1.3 ± 0.5

[a] *N = 9* [b] *p < .001, t-test for paired data, during to pre.*

In the present study there was no attempt to assess the Nb wave since the variability precludes using it as a reliable way of assessing the subtle changes in neural processing, which could be expected during meditation. Instead, we placed emphasis on wave V, Na wave, and Pa wave. The subjects of our earlier study (Telles & Desiraju, 1993), had been practicing meditation for several years, and they had evolved individual methods of focusing the mind for meditation. For example, some subjects would mentally focus on the visual image of the syllable 'Om' as it is written in Sanskrit, while other subjects would allow their thoughts mentally to encompass a limitless expanse (e.g., the sky or the ocean).

In the present study, the senior subjects had comparable experience of meditation, but this group attended a 10 day retreat during which they were given lectures and instructions on meditation. During the actual practice all of them were instructed to focus attention on the visual image of "Om," while mentally chanting it.

One can speculate that subtle differences in the mental processes during meditation, could have explained the intersubject differences in the changes in our earlier study cited above since these differences in MLRs could not be correlated with differences in age, or meditation experience. Similarly, the consistency in the mental processes during meditation among the subjects of the present study could explain why changes in the Na wave during meditation were consistent for the whole group.

These changes in the Na wave occurred in both senior and naive subjects (though in opposite directions) during meditation, and during control session conducted on senior subjects. However, wave V and Pa wave did not change. 1t has been postulated that the Na wave may be due to activity at the mesencephalic or diencephalic level (Deiber, Ibanez, Fischer, Perrin, &

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Mauguiere 1988). Hence, either mentally repeating 'one' or meditation on 'Om' appears to alter neural processing at the same level. However, the nature of change is dependent on whether subjects are "senior" or "naive," and occurs in opposite directions during the two sessions in senior subjects, and in the same direction during both sessions in naive subjects. An increase in amplitude of MLRs has been interpreted as an indicator of increased efficiency in activating the neural generator (Woods & Clayworth, 1985). Hence, it appears that meditation in 'senior' subjects facilitates neural activity at mesencephalic or thalamic (medial geniculate) level, similar to that noted in subjects practicing consciously regulated yogic breathing or pranayama (Telles, Joseph, Venkatesh, & Desiraju, 1993). In contrast, in naive subjects meditation inhibits neural activity at this level. The same result (i.e., inhibition) is also seen in senior subjects while mentally repeating "one." These findings could be correlated with the facts that (a) 'senior' subjects found meditation on "Om" less effort than mental repetition of "one," whereas (b) "naive" subjects felt the opposite i.e., they felt that both meditation and repeating 'one' required effort, which was greater for the former.

Hence, the results of the present study may provide objective correlates for the altered mental state during meditation. These results can, perhaps, be correlated with the subjective experiences of the volunteers.

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Indian J Med Res [B] 98, October 1993, pp 237-239.

RECORDING OF AUDITORY MIDDLE LATENCY EVOKED POTENTIALS DURING THE PRACTICE OF MEDITATION WITH THE SYLLABLE "OM"

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Middle latency auditory evoked potentials were examined in 7 proficient subjects during the practice of meditation on the syllable "Om", to determine whether these potentials would differ significantly from those recorded during the baseline state without practicing meditation. Similar records were also obtained in 7 "naive" subjects, matched for age, before and during a control period which involved sitting with eyes closed, and with no special instructions for focusing their thoughts. There was considerable inter-subject variability in the different components. However, during meditation there was a small but significant reduction in the peak latency of the Nb wave (the maximum negativity occurring between 35 and 65 msec). This reduction was observed consistently during the 3 repeat sessions of each subject, while the "naive" subjects did not show this change. These results suggest that the inter-subject variability of middle latency auditory evoked potentials precludes using them as the method of choice for assessing the effects of meditation. The small but consistent decrease in the Nb wave peak latency, indicates that the middle latency auditory evoked potentials do change with meditation. However, the variability of the potentials may mask subtle changes.

It is reported[1] that near field or long latency auditory evoked potentials (AEPs) showed no consistent change with Transcendental Meditation (TM). Another study[2] reported a reduction in far field (short latency) wave V peak latency following meditation. As It is known that far field AEPs alter with meditation, while near field/long latency potentials do not change, the present study was undertaken to assess the effects of meditation on middle latency AEPs. Such data can help in understanding how neural processing at various levels could change differently during a meditation practice in which thoughts are focused on a word or phrase without conscious effort to do so (i.e., meditation on the syllable "Om"), which is the principle that is also followed in transcendental meditation (TM).

MATERIAL & METHODS

Seven normal healthy male volunteers in the age range of 29 to 55 yrs (the average being 42.3$\pm$ 9.8 yrs), who were experienced in meditation (range 5-20 yrs), were studied. Using identical stimulus conditions, records were also obtained on 7 age-matched 'naive' male subjects with ages ranging from 30 to 55 yrs (average 45.6$\pm$9.5 yrs) who did not meditate.

Each session was of 32 min duration, 20 min spent in meditation, and the two 6 min periods before and after meditation were spent sitting relaxed, with eyes closed. These sessions were repeated thrice in each subject. The meditators were also studied during 3 control sessions, which were similar in design except that the 20 min period which was meant for meditation was spent "just sitting" with eyes closed. The 7 "naive" subjects were studied in 3 repeat sessions which followed the same sequence as the "control" sessions. The effect of focusing

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on a meaningless word/syllable could not be checked, and therefore the results cannot help in understanding the changes which occur specially when focusing on a meaningful symbol.

The meditation practice is claimed to attain a single thought state, in deep relaxation. The single thought is the syllable 'OM' which is chanted aloud during the initial training in meditation, which subsequently leads to an effortless mental chanting of the syllable.

Middle latency auditory evoked potentials (AEP-MLRs) were recorded from Cz-Al with the preamplifier bandwidth set at 1-1500 Hz, in the 70 msec post-stimulus time period. A total of 1500 responses were averaged for each record (NICOLET, USA, Clinical Averaging Package, 1980 version). Click stimuli of 40 msec duration were delivered at 5 Hz binaurally through acoustically shielded earphones (Amplivox, UK). The intensity was set at 1½ times the threshold of hearing noted with the above stimulus parameters. This was 45 dB HL on an average, low enough to allow the meditators to be undisturbed and yet of sufficient intensity to allow recording of the potentials consistently. Peak latency of Na, Pa, and Nb waves were measured from the baseline values at the beginning of the sweep. Latency was measured from the time of click delivery.

The AEP-MLRs components were as follows the Na wave was the largest negative peak between 14 and 18 msec, Pa wave as the largest positive peak between the Na wave and 35 msce, and the largest negative peak between 35 and 65 msec was the Nb wave. These descriptions are similar to those in other studies on AEP-MLRs[3].

Values of peak amplitudes and peak latencies were averaged for each of the 3 periods during the repeat sessions of a subject. Statistical analysis of changes between (i) Meditation or control periods and the preceding eyes closed period; (ii) between meditation and control periods was done by using the paired t-test. For the 'naive' subjects the values of the control period were compared with those of the preceding period.

RESULTS & DISCUSSION

The Nb wave varied considerably among subjects (with a range of 35 to 65 msec). However, for the group as a whole, the Nb wave peak latency decreased significantly ($P<0.05$, paired t-test) during meditation (group mean $\pm$SD 49.5 $\pm$ 7.3 msec), as compared to the preceding period (group mean $\pm$ SD 51.3 $\pm$ 6.1 msec). This change was consistent for each subject during repeat sessions. There was no significant change during the control period (group mean $\pm$SD 51.4 $\pm$ 7.8 msec) versus its preceding period (group mean $\pm$ SD, 49.9 $\pm$ 8.4 msec). Also, the 7 'naive' subjects did not show any change in Nb wave latency between the control period (group mean $\pm$SD 54.0$\pm$ 5.9 msec) and the preceding period (group mean $\pm$SD 53.4 $\pm$7.6 msec).

There were no significant changes in amplitude or latency of either Na or Pa waves for both meditators and 'naive' subjects. An idea of the actual values can be had from the group mean obtained in the period preceding meditation or rest. For meditators, the values for Na wave were 16.4 $\pm$ 1.5 msec (latency), 0.7 $\pm$ 0.2 μV (amplitude) and for Pa wave were 31.8 $\pm$ 3.6 msec (latency), 0.9 $\pm$ 0.4 μV (amplitude). For naive subjects the Na wave measures were 16.3 $\pm$ 1.4 msee (Latency), and 0.6 $\pm$ 0.3 μV (amplitude), and for Pa wave 28.0 $\pm$ 2.7 msec (latency), and 1.5 $\pm$ 0.2 μV (amplitude).

The small but consistent reduction in Nb wave latency during meditation shows that neural processing at the AEP-MLRs level does change. From the current knowledge of the

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generators of these waves[4], one may hypothesize that meditation on 'Om' (a meaningful symbol), leads to changes other than at the prethalamic/thalamic/primary cortical areas. This could be the level of the association cortices. No firm conclusions can be drawn as the actual sample size was small. However, while the subject is awake, there is considerable variability of AEP-MLRs due to large, biphasic wave, viz., the post auricular muscle reflex (PM R), which occurs 10 to 14 msec after the stimulus[5]. The same study reported that the waveform became more constant during diazepam induced light sleep. The present study shows that the variability persists during eyes closed rest and meditation, as well. Hence a recording of AEP-MLRs may mask changes in neural activity during meditations. AEP-MLRs would therefore not be the method of choice to assess changes at different neural levels during meditation (as anticipated at the start of this study), even though they possibly change during meditation.

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Indian J Physiol Pharmacol 1995; 39(4): 418-420

SHORT COMMUNICATION

AUTONOMIC CHANGES DURING "OM" MEDITATION

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Abstract: The autonomic and respiratory variables were studied in seven experienced meditators (with experience ranging from 5 to 20 years). Each subject was studied in two types of sessions - meditation (with a period of mental chanting of "OM") and control (with a period of non-targetted thinking). The meditators showed a statistically significant reduction in heart rate during meditation compared to the control period (paired 't' test). During both types of sessions there was a comparable increase in the cutaneous peripheral vascular resistance. Keeping in mind similar resulta of other authors, this was interpreted as a sign of increased mental alertness, even while being physiologically relaxed (as shown by the reduced heart rate).

Key words *: Oxygen Consumption; Metabolism; Yoga; Meditation.*

INTRODUCTION

Mentally chanting "OM" was shown to increase the efficiency with which sensory information was processed in subjects with more than 10 years of meditation experience, whereas mentally chanting "one" had the opposite effect (1). These changes occurred mainly at the mesencephalic or diencephalic level. Another study of 7 proficient subjects (3 of whom had 20 years experience of meditation), revealed that mental chanting of "OM" activated higher neural centres, i.e. the association cortices (2). Mental chanting of "OM" leads to a single thought state, and a subjective feeling of deep relaxation. Hence the present study was carried out to find out whether "OM" meditation would also cause changes in the autonomic and metabolic functions of the seven experienced meditators whose neural responses to the meditation were described above (2).

METHODS

Subjects

The study was carried out on 7 normal, healthy male volunteers in the age range of 29 to 55 years (mean $\pm$ SD, 42.3 $\pm$ 9.8 years). They were all committed meditators with experience ranging between 5 and 20 years. The details of the study were explained to the subjects and their signed informed consent was taken in accord with the ethical guidelines of the Indian Council of Medical Research, New Delhi.

Design of the study

Each session was of 32 min duration, of which 20 min were spent in meditation, preceded and followed by two 6 min periods of sitting relaxed, with eyes closed. Subjects were also studied in control sessions which were of the same duration as the meditation sessions, and similar in design except that the 20 min period was spent sitting relaxed with eyes closed, and non-targetted thinking (instead of meditation). Meditation involved mental chanting of "OM", while sitting comfortably, with eyes closed. Both types of sessions were repeated on three separate days.

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Parameters studied

Recordings of autonomic and respiratory variables were made on a 10 channel polygraph (Model 10, Polyrite, Recorders and Medicare systems, Chandigarh, India). EKG was recorded using the standard limb lead I configuration. Heart rate was obtained by counting the number of QRS complexes per 40-sec intervals continuously. Epochs of 40 sec were chosen to be able to correlate this data with that of subjects practicing other meditations (3). This has been described in the discussion. Palmar skin resistance (SR) was recorded using 2 silver chloride disc electrodes filled with electrode jelly (CSR Technocarta, Hyderabad, India), placed 4 cm apart on the palmar surface of the right hand. SR values were sampled continuously at 20-sec intervals. Skin blood flow was recorded using a photo-electric plethysmograph placed over the left thumb nail. The amplitude of six plethysmogram waveforms were calculated in each minute. Two nasal thermistors placed one at each nostril were used to record respiration. The number of breath cycles in each minute was calculated to give the respiratory rate. Oxygen consumption was recorded using the closed circuit Benedict-Roth apparatus. In this method, the subject breathed into an oxygen tank wearing a close fitting mask, and with a nose clip. The exhaled carbon dioxide does not enter the tank, as it is absorbed by soda lime. The difference between the initial and final volumes of oxygen in the tank is the amount of oxygen consumed by the subject in a given period of breathing (i.e. 5 min). The recording laboratory had a temperature of 25 ± 1^0C, with relative humidity about 70 percent. The values were corrected for standard temperature and pressure.

The OC recordings were made before and after meditation, but not during meditation. Polygraphic recordings were made before, during, and after meditation.

Values of the 5 variables mentioned above were averaged for each of the 3 periods of a session viz. before, during and after meditation (or the control procedure). Statistical analysis of these averaged values was done to reveal significant differences between (a) before versus during meditation (or control) and (b) during meditation versus during control periods, using the paired 't' test.

TABLE 1

Autonomic and respiratory variables recorded in 7 meditators. Values are group mean ± S.D.

Variables Studied	Meditation Session		Control Session	
	Pre	During	Pre	During
Heart rate (Beats per 40 sec)	47.00 ± 5.00	46.90** ± 4.30	47.20 ± 4.90	47.60 ± 4.80
Respiratory rate (Breaths per min)	10.80 ±3.60	10.40 ± 3.30	10.50 ± 3.40	11.10 ± 3.20
Skin resistance (Kilo ohms)	412.90 ± 129.90	446.60 ± 107.10	307.40 ± 123.40	335.70 113.80
Finger plethysmogram Amplitude (mm)	1.00 ± 0.20	0.70* ± 0.20	1.10 0.20	0.70# ± 0.20

** $p < 0.001$ during meditation versus during control (paired 't' test)
# $p < 0.05$ before versus during period (paired 't' test)

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Oxygen consumption was recorded immediately before and after the meditation period, but not during.

Oxygen Consumption	Pre	Post	Pre	Post
ml/min STPD	454.00 ± 192.00	386.20 ± 68.70	480.30 ± 153.00	483.80 ± 232.50

RESULTS

All seven meditators showed a small but statistically significant reduction in heart rate during meditation compared to the control period ($P<0.001$, paired 't' test, Table 1). There was a significant and comparable decrease in finger plethysmogram amplitude, during the meditation and control periods compared to the preceding periods ($P<0.05$, paired 't' test, in both cases). There was also a non-significant trend of reduction in the oxygen consumption following meditation ($P>0.05$, paired 't' test). The group average values ± SD for all 5 variables are as shown in Table 1.

DISCUSSION

The present study revealed a significant decrease in heart rate during mental chanting of "OM", which is suggestive of psychophysiological relaxation. The non- significant trend of reduction in oxygen consumption also has a similar interpretation. This change is similar to that caused by TM (4), though of smaller magnitude.

However, it is important to note that the actual pre-meditation (or control) values of oxygen consumption of the (senior) meditators of the present study were noticeably higher than those of other meditators (4), and of the general population. Since it is usually thought that yoga practitioners have lower oxygen consumption values than those who do not practise yoga, these results are difficult to explain. There is a report (5) in the literature which demonstrated an increase in the basal metabolic rate (BMR) with six weeks experience in yoga, compared to the period before learning yoga. The BMR decreased, but did not return to the initial value after continuing yoga practice for six weeks. In contrast to the present study, the subjects were not practising meditation, but were practising specific postures (yogasanas) and breath regulation (pranayama). Hence no direct correlation can be made between the two studies, and further assessments are necessary to come to a definite conclusion.

The significant decrease in finger plethysmogram amplitude (i.e. increased peripheral vascular resistance) which occurred during both meditation and control periods is a sign of increased sympathetic tone and hence is also not expected during meditation (4).

While attempting to explain these seemingly contradictory results, it is to be noted that the same individual may simultaneously show changes in two variables indicating opposite states of arousal, e.g. a decrease in heart rate along with reduced skin resistance. While explaining similar contradictory changes in Ananda Marga meditators (6), the authors described the reduced skin resistance as an attempt to prevent intrusion of sleep during the session. Since reduced skin blood flow is known to occur when the subject is alert, as while solving arithmetic problems mentally (7), the present study might indicate that chanting "OM" mentally causes increased alertness (reduced finger plethysmogram amplitude), even though the subject was more relaxed (reduced heart rate).

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HEART RATE AND RESPIRATORY CHANGES ACCOMPANYING YOGIC CONDITIONS OF SINGLE THOUGHT AND THOUGHTLESS STATES

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It has been established (1, 2) that certain yogis can alter the patterns of their cardiovascular functions voluntarily. This report presents information obtained in a subject who practised yoga of thoughtless state for many years. The heart rate and respiratory changes associated with states of thought control have been recorded. Informed consent was obtained from the subject for the study.

YS was a 76 year old healthy and active male, at the time of the study. He was well experienced since childhood in practising asanas, pranayamas and thought control. He stated that he achieved considerable control over his mind, and could change from a 'single thought' to 'no thought' state at will. The EKG of standard limb lead II and respirogram via a mercury strain gauge wrapped around the chest, were recorded on a Beckman dynograph, during a test session, when on instruction he changed from a normal condition, to 'single thought', 'thought', and to "no thought" state, and vice versa, 4 times with approximately 5 min gap of relaxation in shavasan in between the 4 times.

TABLE 1

Heart rate and respiratory changes in altered states of thought.

State	Heart rate per minute	Respiratory rate per minute
Before Shavasan	64.00 (n = 1)	19.00 (n = 1)
Shavasan	63.10 ± 0.20 (n = 4)	17.50 ± 1.50 (n = 4)
Single Thought	64.40 ± 0.97* (n = 4)	15.30 ± 2.50 (n = 6)
No Thought	67.50 ± 1.30** (n = 4)	10.00 ± 0.80** (n = 4)

**P<0.05, ** P<0.01 by comparision to the value during Shavasan (student t-test, two tailed), n = number of values averaged.*

There was a significant increase in heart rate during the 'single thought' state compared to the baseline (eyes closed sukhasan), and a further increase during the 'no thought' state (Table I).

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In contrast, the changes in respiration were different for the 2 states: during 'single thought' state there was an increase in rate and regularity of respiration, Whereas during the 'no thought' state there was a significant reduction in the rate and (regularity (Fig.1). It is noteworthy that although the respiratory changes are in opposite directions, the heart rate changes are in the same direction (increase).

This is an example showing changes of heart rate and respiration accompanying a yogic subjective activity intended to alter the state of mind alone.

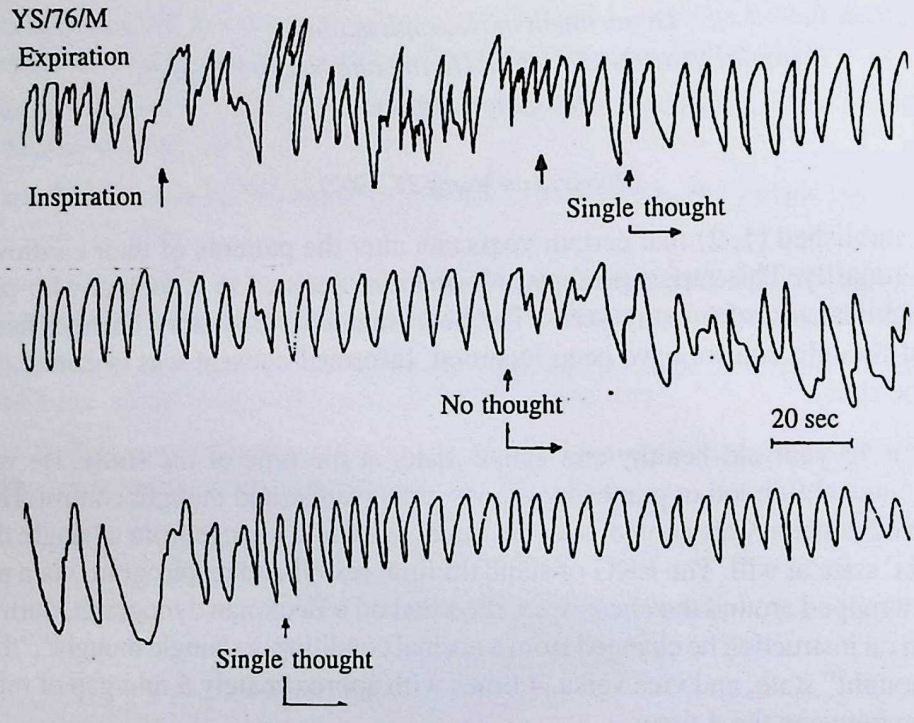

Figure 1. Respirogram continuous record. Between the first pair of arrows and subject was talking.

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AUTONOMIC CHANGES WHILE MENTALLY REPEATING TWO SYLLABLES - ONE MEANINGFUL AND THE OTHER NEUTRAL

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Abstract : Autonomic and respiratory variables were recorded in 12 volunteers in three types of sessions (1) Before, during and after a test period of mentally repeating a meaningful syllable 'OM' (MOM session) ,(2) A similar session except that the test period was spent mentally repeating a neutral word 'one' (COM session), (3) A session with non-targeted thinking (NT session). The subjects were familiar with both syllables, and had been meditating on 'OM' for 20 days. During the test periods of both MOM and COM sessions the rate of respiration (RR) and heart rate (HR) decreased significantly [two factor ANOVA (RR), paired t test (RR. HR)],compared to the pre period, mental repetition of 'OM' (but not 'one') caused a significant decrease in skin resistance level (SRL) (paired t test). This was taken to mean that the subject recognized the significance of the syllable. No significant change occurred during NT sessions.

Key words: *relevant syllable; irrelevant syllable; skin resistance; breath rate; heart rate.*

INTRODUCTION

The syllable 'OM' is known to have profound significance in Indian culture. Mental repetition of this syllable was shown to cause significant changes in middle latency auditory evoked potentials, which were suggestive of a facilitation of neural activity at either mesencephalic or diencephalic level (1). In contrast mentally repeating a neutral syllable 'one', inhibited neural activity at the same level. This was observed in subjects who had been regularly meditating on 'OM' every day for more than 10 years ('experienced meditators'). In 'naive' subjects, with 15 to 20 days of experience in meditation, repeating both 'OM' and 'one' caused the same effect, viz an inhibition of neural activity at mesencephalic or diencephalic level.

It was also reported that highly experienced meditators (20 years experience on an average) show a significant reduction in heart rate and a non significant trend of reduction in oxygen consumption while mentally repeating 'OM' compared to a period of non targeted thinking (2). These subjects simultaneously displayed an increase in cutaneous vasoconstriction, which was interpreted as an increase in mental alertness (3), in the presence of other signs of reduced arousal (reduced heart rate and oxygen consumption).

The present study was conducted to compare the autonomic effects of mentally repeating a meaningful syllable with mental repetition of a neutral one and with non targeted thinking, in subjects who were acquainted with both syllables, and had been meditating on the meaningful syllable for 20 days, comparable to the naive subjects described earlier (1). The duration of meditation was believed to influence the ability to comprehend the significance of the syllable and a comparison with results obtained in experienced meditators, could be made.

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METHODS

Subjects

There were 12 volunteers (4 male, 8 female) with normal health as determined by a routine medical examination and ages ranging from 25 to 40 years (Mean 30.1, SD 6.2 years). They had been practising 'OM' meditation for 20 days twice a day, 15-min at a time, prior to testing. During a meditation session, subjects would keep their eyes closed and mentally repeat the syllable.

Design of the study

The subjects were assessed in 3 separate sessions conducted on different days, at the same time of the day. Each session lasted for 25 min. The test period was for 15 min, while the 2 periods preceding and following it, were for 5 min each. For all 3 sessions, subjects remained recumbent (supine) with their eyes closed while recording the 'pre' and 'post' periods. Instructions during the 'test' period (15 min) differed among the 3 sessions. In the first 8 min of the 'OM' repetition session (MOM) subjects were given instructions using a pre-recorded audiotape, to relax the body from the toes upwards, naming each part of the body. The next 7 min of the 15 min period were spent in mentally repeating 'OM'. During the test period of the 'control' session (COM), the same sequence was followed, i.e. 8 min following the same pre-recorded instructions to relax as for the MOM session, followed by 7 min of mentally repeating 'one'. During the session with non targeted thinking (NT), subjects spent the first 8 min of the test period following the same pre-recorded instructions as for MOM or COM test periods. The next 7 min were spent in non targeted thinking. These two periods (8 min of guided relaxation and 7 min of specific practice) were decided upon, as subjects reported that they were able to relax while continuously repeating a syllable mentally for a given period, when it was preceded by guided relaxation. The data acquired during the 15 min period as a whole were analyzed. Also, the data obtained during the first 8 min (guided relaxation) and during the next 7 min ('OM'/ 'one' repetition /non targeted thinking) were examined separately to note any significant change during either period.

- The order of the 3 sessions (MOM, COM, NT) was varied in a random fashion for the subjects. Hence 4 subjects had MOM sessions on day 1, with COM and NT sessions on the next 2 consecutive days. Another 4 subjects had sessions in the order COM, NT, MOM. The 4 remaining subjects followed the order NT, MOM, COM.

Recording conditions and parameters

The sessions were conducted in a dimly lit, sound attenuated cabin. A model 10 polygraph (Recorders and Medicare, Chandigarh, India) was used to record the EKG, respiration, digit pulse volume (DPV) and skin resistance (SR). EKG was recorded using the standard bipolar limb lead I configuration and an AC bioamplifier with 1.5 Hz high pass and 75 Hz low pass settings. Respiration was monitored with a volumetric pressure transducer. The subject was asked to stand erect and the transducer was fixed around the trunk, 5 cm below the lower costal margin. A photoplethysmogram was placed on the volar surface of the distal phalanx of the left index finger to assess the digit pulse volume (DPV). Skin resistance (SR) was recorded using Ag/AgC1 disk electrodes attached to the volar surfaces of the distal phalanges of the right index and middle fingers, with a reference electrode on the volar surface of the right forearm. Electrode gel (Medicon, Madras, India) was used, and a constant current of 10 μA was passed between the electrodes. The signal was processed through a DC preamplifier. The EEG was recorded with Ag/AgC1 disk electrodes placed at F3, F4, 01 and 02 (4), each referenced

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to the contralateral earlobe. The EOG and EMG were recorded as for standard polysomnography (5). For EEG and EOG the time constant was 0.1 s, for EMG it was 1.0 s). Recordings of EEG. EOG and EMG allowed any sleep episodes to be detected with the purpose of excluding them from analysis.

Data acquisition and analysis

The skin resistance (SR) trace was sampled every 30 s. The amplitude of the digit pulse was sampled from the ascending portion of the wave at 30 s intervals and converted to mV as described elsewhere (6). The heart rate (HR) was calculated by counting the QRS complexes in successive 60 s epochs continuously, to give the HR in beats per min (bpm). The rate of respiration (RR) was similarly calculated by counting the number of respiratory waves also in successive 60 s epochs continuously, and noting the RR as cycles per min (cpm).

Data were analyzed in two ways: (i) a two factor ANOVA using data obtained in the 'pre' and 'test' periods, but not in the 'post' period. The ANOVA was used to examine two factors, viz. a) the two states ('pre' versus 'test' - Factor A) and b) the three sessions (MOM, COM, NT Factor B). The multiple comparison Tukey test ('least significant difference' test) was used to make pairwise comparisons, e.g. 'pre' (MOM) versus 'test' (MOM).

(ii) The 't' test for paired data was used to compare the data of 'test' and 'post' periods with those of the corresponding 'pre' period.

RESULTS

General remarks

No sleep episodes were detected and hence the entire record was used for analysis. There were also (i) no significant changes in any of the parameters during the first 8 min (guided relaxation) of the 'test' periods, compared to the 'pre' periods, and (ii) the (non significant) changes observed during the first 8 min of the 'test' period did not differ among the 3 sessions. It was decided to use the data of the next 7 min of the 'test' period ('OM'/ 'one' repetition/non targeted thinking) for statistical analysis, so that the duration of this period (7- min) was comparable to that of the 'pre' and 'post' periods (5 min). The group mean values ± SEM are provided in Table 1.

TABLE 1 : Autonomic variable during pre test and post period of MOM, 'OM' repetition, COM, 'One' repetition, and NT, non targeted thinking sessions. Values are group mean ± SEM.

Session	Period	Heart rate (bmp)	Digital pulse volume (mV)	Skin resistance(K)	Breath rate (cpm)
MOM	Pre	70.0 ± 1.9	1.4 ± 0.3	151.0 ± 32.3	15.5 ± 1.7
	Test	66.6 ± 2.3*	1.6 ± 0.3	121.0** ± 26.8	12.9 ± 1.2***
	Post	70.9 ± 2.2	1.1 ± 0.2	99.0*** ±32.3	13.5 ± 1.7*
COM	Pre	70.9 ± 1.8	2.0 ± 0.2	170.0 ± 35.2	15.1 ± 1.3
	Test	69.4 ± 2.0*	2.1 ± 0.1	177.0 ± 42.3	10.4 ± 1.3***
	Post	69.3 ± 1.9*	1.6 ± 0.1	182.0 ± 42.4	13.3 ± 1.5*
TEST	Pre	70.4 ± 1.9	1.8 ± 0.1	165.0 ± 37.8	14.9 ± 1.4
	Test	69.9 ± 1.8	1.9 ± 0.1	166.0 ± 37.4	14.1 ± 1.6
	Post	70.9 ± 1.8	1.5 ± 0.3	144.0 ± 36.9	14.5 ± 1.5

**P<.05, **P<.01, ***P<.001 Paired 't' test, compared to pre.*

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Two factor ANOVA

The two factor ANOVA showed a significant difference between the respiratory rate (RR) of 'pre' and 'test' periods, i.e. Factor A = 'pre' versus 'test' [F = 5.28 (F.05 (2) 1.66 = 5.27) hence P < .05 or P = .05]. The F value has been derived by linear interpolation according to the method described (7), based on the F values for DF = 1, 60 and DF = 1, 70 in the standard table. The Tukey multiple comparison test did not reveal a significant difference between any two mean values. In all comparisons q was less than 3.50, [since q (6, 60) = 3.75 at .10 level, therefore P>.10]. Here 60 is utilized as the next critical value after 66, which is not listed in the table 1.

There was no significant difference between the 3 sessions (Factor B), or of interaction between the Factors i.e. A x B (P>.10, in both cases). For the remaining parameters (heart rate, digit pulse volume and skin resistance level), the two factor ANOVA did not show significant differences between the values of 'pre' and 'test' periods (Factor A), between the three sessions (Factor B), or the interaction between the factors (A x B), (P>.20 in all cases).

Paired 't' test

The HR during the 'test' periods of both MOM and COM sessions was significantly lower than that of the corresponding 'pre' period, by an average of 3.4 bpm and 1.5 bpm, respectively (P<.05 in both cases). The HR remained significantly low after COM (P<.05). There was also a significant decrease in RR in the 'test' periods of both MOM and COM sessions (by an average of 2.6 cpm and 4.7 cpm, respectively, P<.001, in both cases, compared to the corresponding preceding period). This effect persisted during the 'post' periods of both MOM and COM sessions (a decrease of 2.0 cpm and 1.8 cpm respectively, P<.05 compared to the corresponding preceding period).

There was a significant decrease in skin resistance level (SRL) during the 'test' period of the MOM session, compared to the preceding period (P<.01). There was also a significant decrease in SRL in the 'post' period of the MOM session compared to 'pre' (P<. 0 1).

There was no difference in the trend of results according to the order of the three sessions (MOM, COM, NT) though the small sample size (four subjects with each sequence) precluded using statistical analysis.

DISCUSSION

The present study has shown that mental repetition of a syllable either meaningful (MOM) or neutral (COM), causes a decrease in heart and breath rate. Non targeted thinking (NT) for the same period of time does not have a similar effect. This result is similar to reports about the physiological changes during Transcendental Meditation (TM) (8, 9). During the practice of TM subjects silently repeat a particular mantram (see below) throughout each 20 min session, returning focus to it whenever attention wanders (10). A unique mantram is assigned to each individual, with the idea that a particular sound resonates optimally with a specific nervous system. The mantram is not 'meaningful' in the sense used in the present study.

It was noted that the change which was unique to the repetition of the meaningful syllable ('OM'), during MOM sessions was a significant decrease in the skin resistance level (SRL). This change is opposite to that observed in the studies on TM by (8.9), in which an increase in skin resistance was reported.

It is now well recognized that different subdivisions of the sympathetic nervous system need not always be activated simultaneously. The responses to a given stimulus vary, depending

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on the individual and on the stimulus (11). Hence a subject may have a reduction in HR (reduced cardiac sympathetic tone) at the same time as a decrease in skin resistance level (SRL), which is believed to be due to increased sudomotor sympathetic tone. The interpretation of change in skin resistance is open to continuing debate. The sweat glands are believed to be the major contributors to changes in the spontaneous electrodermal activity (EDA) as is observed by recording the SRL (12). Human sweat glands are generally known to receive predominantly sympathetic cholinergic innervation (13). Hence though the EDA is regulated by the sympathetic nervous system, the EDA and cardiac sympathetic control systems are recognized to be organized differently (14). The HR is believed to be influenced by somatic activity and movement control mechanisms, whereas the EDA appears to be determined primarily by motivational or attentional arousal. Hence mental repetition of both 'OM' and 'one' may reduce somatic activity (HR reduction), while the mental repetition of 'OM' appears to cause an increase in attentional arousal (reduced SRL), as well.

In addition to the conventional concept of an increase in skin resistance signifying an increase in sympathetic tone, the sensitivity of the skin resistance (response) to significant stimuli is well known (the 'lie detection test').

It was reported (15) that the generation of frequent and large electrodermal skin responses were the only indication that in prosopagnosic patients, who have lost their ability to recognize faces, the process of recognition is still taking place. It was also noted that in these patients the results of cognizance were not available to consciousness. While these findings cannot be directly applied to the present results, they may suggest that even though mental repetition of both 'OM' and 'one' cause comparable changes in HR and RR, the neural processes involved in recognizing the significance of the syllable 'OM' are active, as reflected by the decrease in SRL.

Previous studies have demonstrated that subjects with a short experience of meditation (comparable to the subjects of the present study), show similar inhibition in sensory neural processing at mesencephalic and diencephalic levels, while repeating both 'OM' and 'one' (1). In the same study, in experienced meditators neural processing at these levels was significantly facilitated while repeating 'OM'. These observations on sensory neural processing, were based on recordings of middle latency auditory evoked potentials. In both short duration and experienced meditators there were significant changes (in opposite directions) in the amplitude of the Na wave. This is a negative wave occurring between 14-18 msec after the stimulus, with a neural generator at mesencephalic /diencephalic level (16). An increase in peak amplitude observed in experienced meditators, suggests facilition of sensory neural processing (17). In a separate study (2) on the autonomic changes in experienced 'OM' meditators, there was no change in the skin resistance level while repeating 'OM'. This is in contrast to the short duration meditators of the present study.

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Hence to sum up the results of the present and previous studies, (i) a decrease in HR, RR (conventional indicators of relaxation) follow the mental repetition of any syllable, (ii) subjects who have brief (20 days) experience of medication on a meaningful syllable ('OM'), show a significant decrease in SRL during repetition of that syllable, but not while repeating a neutral syllable or during non targeted thinking. Subjects with longer meditation experience do not show this change, (iii) experienced meditators show significant facilitation of sensory neural processing at mesencephalic /diencephalic levels while repeating the syllable on which they meditate. Naive meditators do not show this change. These results suggest that the process of understanding the significance of a meaningful syllable may be continuous, and is significantly influenced by the duration of meditation. The decrease in SRL was observed in naive meditators but not in experienced meditators, hence this change may represent an intermittent stage during

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which changes in sensory evoked potentials (EPs) are not yet obtained. The present results also support the idea that the SRL may indicate cognitive involvement in the object of meditation in addition to being a conventional indicator of sympathetic tone.

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AUTONOMIC CHANGES IN BRAHMAKUMARIS RAJA YOGA MEDITATION

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This report presents the changes in various autonomic and respiratory variables during the practice of Brahmakumaris Raja yoga meditation. This practice requires considerable commitment and involves concentrated thinking. 18 males in the age range of 20 to 52 years (mean 34.1 ± 8.1), with 5-25 years experience in meditation (mean 10.1± 6.2), participated in the study. Each subject was assessed in three test sessions which included a period of meditation, and also in three control (non-meditation) sessions, which included a period of random thinking. Group analysis showed that the heart rate during the meditation period was increased compared to the preceding baseline period, as well as compared to the value during the non-meditation period of control sessions. In contrast to the change in the heart rate, there was no significant change during meditation, for the group as a whole, in palmar GSR, finger plethysmogram amplitude, and respiratory rate. On an individual basis, changes which met the following criteria were noted: (1) changes which were greater during meditation (compared to its preceding baseline) than changes during post meditation or non- meditation periods (also compared to their preceding baseline); (2) Changes which occurred consistently during the three repeat sessions of a subject and (3) changes which exceeded arbitrarily-chosen cut- off points (described at length below). This individual level analysis revealed that changes in autonomic variables suggestive of both activation and relaxation occurred simultaneously in different subdivisions of the autonomic nervous system in a subject. Apart from this, there were differences in patterns of change among the subjects who practised the same meditation. Hence, a single model of sympathetic activation or overall relaxation may be inadequate to describe the physiological effects of a meditation technique.

Key words: *Autonomic change; Meditation; Heart rate; Skin resistance; Finger plethysmogram, Respiratory rate.*

INTRODUCTION

Most of the reports on physiological effects of meditation have dealt with Transcendental Meditation (TM), Zen and Tantric Yoga. TM was adapted from the Indian Yogic tradition by Maharishi Mahesh Yogi. Practising TM, subjects sit in a comfortable posture and silently repeat a given mantram, returning their attention to it whenever attention wanders. Zen meditation forms an integral part of Zen Buddhism. Subjects sit in the lotus position, keep their eyes open and their attention focussed (initially on their breathing, and later on, on a 'Koan' or riddle). Tantric Yoga involves intense concentration of attention, with the ultimate aim of channelling all of ones energies into the spiritual energy of union with the object of devotion.

The practice of TM was reported to cause reductions in heart rate, respiratory rate, and oxygen consumption, and to increase the level or stability of the electrodermal response (Wallace, 1970; Wallace et al., 1971). A later report (Heide, 1986), noted a difference in the heart-rate response but not in the electrodermal response evoked by 80 dB tones, when TM practitioners and non-meditators were compared.

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Contradictory results were observed in Zen and Tantric meditations. One set of studies reported changes suggestive of autonomic activation (Hirai, 1974; Corby et al., 1978), whereas another set of studies reported changes suggestive of autonomic relaxation (Kasamatsu and Hirai, 1966; Sugi and Akutsu, 1968; Elson et al., 1977)

With the background of contradictory reports on the effects of meditation techniques, the present study was carried out to determine whether a given meditation technique would bring about the same effects in all the subjects practising it. Practitioners with 5 or more years of experience in Brahmakumaris Raja yoga meditation were chosen. This technique requires considerable commitment and involves concentrated thinking.

METHODS

Subject

18 healthy male volunteers participated in this study They were between 20 and 52 years (mean ± S.D. was 34.1 ± 8.1 years), and they had 5-25 years experience of the meditation procedure (mean ± S.D. was 10.1 ± 6.2 years). The study was explained to the subjects and their signed informed consent was taken, according to the ethics laid down by the Indian Council of Medical Research New Delhi.

Meditation

The Brahmakumaris Raja (= Raj) yoga meditation (BK) has spread from the organisation's headquarters at Mount Abu (Rajasthan, India) throughout India, and to other countries as well. During meditation, subjects sit in a comfortable posture with their eyes open, and with gaze fixed on a meaningful symbol (a light). At the same time they actively think positive thoughts about a Universal force pervading all over, as light and peace (Easy Raj Yoga, 1981).

Test sessions

Each subject was assessed in two types of session involving either a meditation period (with targeted thinking) or a non-meditation period (with random thinking). Each type of session was repeated thrice on different days, but at the same time of day.

During the recording session the subject sat in a comfortable chair in a dimly-lit, air conditioned and sound-attenuated cabin. Subjects were observed throughout on a closed-circuit television. Each session was of 36 min duration, of which 24 min was spent in meditation (with eyes open) preceded and followed by 6-min periods of relaxation, also with eyes open. These meditation sessions were repeated thrice by each subject on different days. In addition, there were also three non-meditation ('control') sessions, which were similar in design, except that the period corresponding to the 24 min of meditation was spent sitting relaxed, without targeted thinking.

Data acquisition analysis

Recordings were made on Grass model 78D polygraph. EKG was recorded using a standard limb lead II configuration. Skin resistance (SR) was recorded with AgCl disc electrodes placed approx. 4 cm apart on the palmar surface of the right hand. Electrode gel CSR (Technocarta, Hyderabad, India) was used, and a constant current of 10 μA was passed. Finger plethysmogram amplitude was recorded with a photo-cell transducer kept at the base of the right thumb nail. Respiration was recorded via a rubber stethograph connected through a pressure transducer.

In addition, the EEG was recorded from electrodes placed at F3, F4, 01 and 02, referenced to the contralateral earlobe. Also, EOG and chin EMG were recorded as is usual for sleep-stage

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scoring (Rechtschaffen and Kales, 1968). This allowed any sleep episodes to he detected and excluded from the analysed data.

The SR values were sampled at 20s intervals from the continuously acquired record. The heart rate was obtained by counting the number of QRS complexes occurring in successive epochs of 40s periods analysed throughout. The respiratory rate was calculated from the record by counting the breath cycles in successive 40s epochs continuously. 20s or its multiple (i.e., 40 s) time epochs were used while calculating SR, heart rate and respiratory rate to make it feasible to correlate these data with that of EEG acquired simultaneously and subjected to computerized power spectral analysis in 20s epochs. For the present group of meditators the EEG data have been presented elsewhere (Kulkarni et al., 1988), and have not been reiterated here as no interesting correlations emerged between autonomic and EEG changes. The finger plethysmogram amplitude was calculated from measurement on 20 plethysmogram waves picked up randomly in each 6-min period.

Data analysis was done in two ways. viz., (1). For the group as a whole two statistical tests were used. (a), A two-factor (Factor A, meditation vs. non-meditation and Factor B, pre vs. during) ANOVA was carried out to assess the effects of both factors, as well as the interaction of

Table -1 : Heart rate in different conditions of the meditation and non-meditation sessions of the 18 subjects M, meditation period; pre-M, period preceding Meditation; NM, non-meditation period; n, number of values averaged per subject; pre-NM, period preceding Non-meditation; n.s., non significant.

Subject	Age (years)	Meditation experience (years)	Heart rate per 40 s (mean ±S.D.) Pre-M (n = 20)	M (n=80)	Pre-NM (n = 20)	NM (n=80)
DRN	38	8	51.4 ± 2.8	51.5 ± 2.7	49.6 ± 1.9	49.9 ± 3.3
RR	48	18	42.1 ± 0.8	43.3 ± 1.8	42.9 ± 5.0	43.2 ± 4.5
NAR	28	8	50.4 ± 3.9	52.6 ± 4.0	53.6 ± 3.9	55.5 ± 5.9
MNH	28	5	51.5 ± 1.6	57.5 ± 2.3	47.6 ± 2.9	47.7 ± 2.4
NLN	40	16	44.6 ± 2.6	45.1 ± 1.8	45.8 ± 3.6	45.3 ± 3.2
AM	30	9	54.4 ± 0.6	60.0 ± 2.7	54.9 ± 5.5	53.9 ± 5.1
MN	52	15	56.4 ± 0.9	55.6 ± 0.8	55.9 ± 0.8	52.2 ± 0.9
MG	29	5	50.5 ± 3.5	54.9 ± 2.9	51.6 ± 2.9	51.9 ± 1.9
JGN	34	10	40.9 ± 3.1	48.3 ± 3.0	47.4 ± 0.6	45.8 ± 1.8
SM	41	5	42.8 ± 3.9	43.5 ± 3.5	41.6 ± 1.9	42.0 ± 2.5
DP	20	8	61.0 ± 2.5	60.3 ± 3.5	54.1 ± 1.6	53.5 ± 1.4
SU	38	6	63.0 ± 6.1	62.5 ± 5.1	58.3 ± 5.0	58.5 ± 5.1
SVP	30	5	53.3 ± 1.6	51.7 ± 2.1	51.2 ± 1.5	50.1 ± 2.0
AC	31	18	53.4 ± 0.3	54.1 ± 1.3	51.2 ± 0.7	50.2 ± 1.8.
AG	36	15	62.2 ± 1.6	65.2 ± 2.0	59.8 ± 0.7	58.9 ± 1.4
FE	22	5	39.0 ± 1.4	41.5 ± 0.9	42.1± 2.7	42.5 ± 1.6
MR	33	15	48.5 ± 0.7	48.6 ± 1.1	47.8 ± 3.4	48.5 ± 3.0
GA	35	25	49.2 ± 4.7	51.8 ± 3.6	47.7±5.5	45.7 ± 4.7
Mean ±S.D		50.81±7.1	52.7±36.8	50.2 ±5.3	49.9±5.3	
Paird t-test (two tailed) on data of whole group				t(17) 2.66 P<0.02 (M vs. pre-M)		t(17) 1.19 n.s (NM vs. pre -NM)

Note: paired t-test (two-tailed) M vs. NM. t (17) 3.84 P <0.01

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all four variables listed above (Snedecor and Cochran, 1967; Zar, 1984). (b), A paired t-test (two-tailed) was performed on the averaged data. The values of each variable obtained in the three meditation sessions of a subject were averaged for: (a), the-24 min period of meditation; (b), the corresponding 24 min period of a non-meditation session; (c), the baseline state of the 6-min period in the eyes open state preceding the meditation, or the non- meditation period in the corresponding type of sessions and (d), the post-meditation (or post- non-meditation period). The averaged data of each of the 18 meditators were subjected to the paired t-test (two-tailed) to assess at the group level whether the following comparisons were significantly different: (a), meditation period and its preceding (eyes open) baseline period; (b), non- meditation period and its preceding (eyes open) baseline period; (c), meditation period and non- meditation period and (d), post-meditation period and premeditation period.

(II), On an individual basis data were also examined and changes which met the following criteria were noted: (a), changes during meditation (compared to the preceding period) should exceed those during post-meditation or non- meditation periods (also compared to the initial baseline period); (b), changes should occur in one direction, consistently during the three repeat sessions of a subject and (c), in order to quantify the change, arbitrary cut-off points were selected for each variable as follows: changes in heart rate should be equal to/more than 2 beats / 40 s, similarly for respiration, a change equal to/more than one breath per 40 s, for SR a change equal to more than 10 kΩ and for finger plethysmogram amplitude a change equal to or more than 0.40 cm.

RESULTS

Heart rate

Group analysis. The two-factor ANOVA did not reveal significance of (a), meditation vs. non-meditation ($F = 1.35$); (b), states (pre vs. during) (F 0.31) or (c), interaction between the two factors ($F= 0.50$). In contrast, with the paired t-test, comparison of the data of meditation (M) against premeditation (pre-M) for the 18 subjects as a group showed that the heart rate was increased by 2.1 beats per 40 s during M, and the difference was significant ($P < 0.02$) (see the last row of the column M of Table I). There was no significant change during the non-mediation (NM) period compared to its preceding baseline (paired t-test, two-tailed, see the last row of the column NM of Table 1). A third comparison (M vs. NM) revealed that the heart rate during M was also significantly higher than during NM ($P < 0.01$, paired t-test, two-tailed, last row of the column of the extreme right of Table 1). Also, since one way of removing the regression of each treatment on its baseline is to analyse the change score of heart rate of the 18 subjects (M-pre-M vs. NM-pre-NM). These data were subjected to analysis using the paired t-test, which revealed that the change scores of M (mean = + 1.4 change of heart rate/ 40 s) were significantly different from the change scores of the NM condition (mean = 0.3 change of heart rate/ 40 s ($t (17) 2.97$, $P < 0.01$). Also, the heart-rate values of the meditation condition have a significant correlation with the base line value of the subjects obtained in the pre-meditation period ($r = 0.94$, $P < 0.001$ (2)), or in the pre non-meditation sitting period ($r = 0.93$, $P< 0.00 1$ (2)).

Individual analysis.

The heart-rate data of each subject were also examined separately. Based on the three criteria mentioned above (Methods section, under data analysis), it was noted that in eight subjects there was a definite trend of increase in heart rate during M, whereas one subject showed a decrease in heart rate during NM.

Other parameters (SR, finger plethysmogram amplitude, respiratory rate)

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Group analysis (using both two factor ANOVA, as well as the paired t-test) did not reveal a significant effect of meditation compared to its preceding baseline, or to the non-meditation period ($P > 0.10$ for both tests and in all the comparisons described in detail for heart rate).

The group mean ± S.D. values for these three variables were as follows (1), SR; pre-M = 256.5 ± 62.1 kΩ, M = 246.3 ± 55.8 K, pre-NM = 264.3 ± 47.6 K, and NM = 271.3 ± 41.3 K, (2), Respiratory rate; pre-M = 12.1 ± 2.4 breaths/ 40 s, M = 13.4 ± 3.5 breaths /40 s, pre-NM = 11.9 ± 1.8 breaths /40 s, and NM = 12.2 ± 2.3 breaths /40 s. (3), Finger plethysmogram amplitude; pre-M = 1.68 ± 0.74 cm, M = 1.24 ± 0.64 cm, pre-NM = 1.72 ± 0.71 cm, and NM = 1.66 ± 0.56 cm.

Individual level analysis (based on the three criteria cited in the Methods section) has been summarized in Table II. It is given below in detail. (1), SR; During M, 5 subjects showed a decrease and 3 showed an increase. In contrast, during NM 7 subjects showed an increase and 3 a decrease. (2), Respiratory-rate changes occurred during M (but not during NM), i.e., 4 subjects showed a decrease, one showed a increase. (3), Finger plethysmogram amplitude; during M, 4 subjects showed a decrease, whereas 2 subjects showed an increase during NM.

DISCUSSION

The most important finding of this study on the effects of Brahmakumaris Raja yoga meditation was a small (but consistent) increase in the heart rate during meditation, compared to the preceding period, as well as compared to the non-rneditation period. In contrast, changes in respiratory rate, finger plethysmogram amplitude and SR were fewer and often in opposite directions for the subjects practising the same meditation. However, they were consistent during repeat sessions of a subject. These individual differences did not seem to be correlated with differences in age, duration of meditation experience, or commitment to meditation. Individual differences in autonomic response specificity have been known for a long time. Detailed descriptions have shown that autonomic responses are a function of both the evoking stimulus (stimulus-response specificity) and of the responding individual (individual response specifity (Engel, 1960). It is interesting to speculate that the contradictory reports on Transcendental Meditation (TM), Zen, and Tantric yoga, described in the Introduction as either 'activating' or 'relaxing', may in fact be due to differences in the individual response patterns.

Table II : Changes in heart rate, paimar GSR, finger plethysmogram amplitude and respiratory rate based on individual level analysis

I, increase; D, decrease; M, Meditation period; Pre-M, period preceding meditation; NM, nonmeditation period; pre-NM, period preceding non-mediation period.

Parameter	*Number of subjects showing change*			
	M against pre - M		*NM against pre - NM*	
	I	D	I	D
Heart rate	8	0	0	1
Palmar SR	3	5	7	3
Finger plethysmogram amplitude	0	4	2	0
Respiratory rate	1	4	0	0

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Holmes (1984) commented that no studies showed consistent differences between resting and meditating subjects in heart rate, electrodermal activity, respiratory rate and other similar variables. However, he stated that in 4 out of 16 experiments, meditating subjects showed greater increases in heart rate than did resting subjects, and none showed decreases. In this study also, the most consistent change was an increase in heart rate during the practice of Brahmakumaris Raja yoga meditation which was suggestive of cardiosympathetic activation, and a possible sign of psychophysiological arousal. This finding can be correlated with the fact that BK meditation requires intense involvement and concentration. The changes in the other variables (though often consistent for an individual) did not reveal any group pattern.

These results suggest that use of some autonomic and respiratory variables (e.g., heart rate) may reveal group effects of meditation, whereas other variables can alter in an individualistic way. Hence, a single model of meditation producing either overall relaxation or overall activation is probably inadequate.

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YOGA BASED GUIDED RELAXATION REDUCES SYMPATHETIC ACTIVITY IN SUBJECTS BASED ON BASELINE LEVELS

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Summary - 35 male volunteers with ages ranged from 20 to 46 yrs were studied in two sessions, of yoga based guided relaxation and supine rest. Assessments of autonomic parameters were made in 15 subjects, before, during and after the practices, whereas oxygen consumption and breath volume were recorded in 25 subjects, before and after both types of relaxation. A significant decrease in oxygen consumption and increase in breath volume were recorded after guided relaxation (paired t test). There were comparable reductions in heart rate and skin conductance level during both types of relaxation. During guided relaxation the power of the low frequency component of the heart rate variability spectrum reduced, whereas the power of the high frequency component increased, suggesting reduced sympathetic activity. Also subjects with a base line ratio of LF/HF >0.5 showed a significant decrease in the ratio after guided relaxation, while subjects with a ratio < 0.5 at baseline showed no such change. The results suggest that sympathetic activity decreased after guided relaxation based on yoga, depending on the base line levels.

INTRODUCTION

A number of reports have described the physiological changes associated with diverse relaxation techniques (Harding, 1996; Smith, Amutio, Anderson, & Aria, 1996; Broms, 1999). Relaxation guided by instructions has been shown to be more effective in reducing physiological arousal than a control session of supine rest (Sakakibara, Takeuchi, & Hayano, 1994). Also, after exercise the heart rate and blood pressure returned to the baseline level sooner, when subjects practiced guided relaxation compared with recovery after rest while supine or seated (Bera, Gore, & Oak, 1998). Specific relaxation techniques may be more effective for certain persons, based on their psychophysiological characteristics (Weinstein & Smith, 1992), and isometric 'squeeze' relaxation has been found to be more likely to induce relaxation compared to meditation, for individuals who have difficulty focusing and less developed stress coping strategies (Weinstein & Smith, 1992).

However, most reports describe post relaxation effects on a group level, regardless of individual differences at base line. Also, most instructions to relax make use of imagery (Rickard, Collier, McCoy, Crist, & Weinberger, 1993) and breathing (Toivanen, Lansimies, Jokela, & Hanninen, 1993). With this background, the present study was conducted to assess whether the present subjects who had a group mean of 30.2 months experience of yoga practice, showed greater reduction in physiological arousal after 'Guided relaxation' (with instructions) as compared to 'Supine Rest' (without instructions). This was considered interesting as both practices (i.e., relaxation with instructions and rest in the supine position are considered to be relaxing by yoga practitioners). Also yoga practice is believed to help reach a state in which external instructions to relax are no longer necessary. Guided relaxation was based on yoga, with breath awareness and chanting, as is usual in yoga practice (Nagendra & Nagarathna, 1988). (ii) As a second aim, subjects were categorized as two groups, based on their baseline levels of LF/HF ratio of the heart rate variability components, which indicate the cardiac autonomic control, and the changes of the two categories of subjects after guided relaxation are presented separately.

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METHOD

Subjects

The subjects were 35 male volunteers, with ages ranging from 20 and 46 years ($M = 27.5$, $SD = 4.7$ yr.) and with an average of 30.2 months ($SD = 25.7$) of experience with yoga practice. All the subjects had completed a residential course in yoga (i.e., for five and a half months) at the residential yoga center. Subsequently, they were staying on at the center for varying durations to participate in other activities and to carry on practicing yoga, which included both shavasana and 'guided relaxation'. As it was not possible to record autonomic variables and oxygen consumption simultaneously, with the equipment used by us, these two assessments were made in separate sessions. For some subjects this number of sessions was too cumbersome, hence one assessment (i.e., autonomic variables or oxygen consumption) was made. Hence the autonomic variables were recorded in 15 subjects before, during, and after Guided relaxation and similarly for Supine Rest; in 25 subjects, the oxygen consumption was recorded before and after Guided Relaxation and before and after Supine Rest. There were 5 subjects who had recordings of both autonomic variables and oxygen consumption.

Design

Subjects were studied in two separate relaxation sessions, viz., guided relaxation and supine rest. The two sessions were on different days at the same time of the day. For half the subjects, alternately, the guided relaxation session was on the first day with the supine rest session the next time. The order was reversed for the remaining subjects. Each session took 20 minutes and consisted of 3 periods, viz., Before (5 minutes), Test (10 minutes), and After (5 minutes). For analysis, the Test period was divided as two, During 1 and During 2, each of 5 minutes. The subjects were sitting at ease before and after the Test periods, and supine during the Test periods This change in posture (i.e., sitting before and after, compared with supine, during), was chosen as the supine posture is one the positions chosen for relaxation by yoga practitioners, and being in the supine position would hence have been similar to supine rest.

Assessment

The oxygen consumption was recorded with a closed circuit Benedict-Roth apparatus (INCO, Ambala, India) using the standard method (Mountcastle, 1980). The subject breathed into an oxygen tank from which exhaled carbon dioxide was excluded by absorption in sodium hydroxide. The subjects were asked to breathe into the mask, which covered their nose and mouth. Recordings were made before and after, but not during test periods.

A 4-channel polygraph (Medicaid Systems, Chandigarh, India) was used to record the electrocardiogram (EKG), respiration, finger plethysmogram and skin conductance level. EKG was recorded using standard limb lead I configuration. The EKG was digitized using a 12 bit analog-to-digital convertor (ADC) at a sampling rate of 500 Hz. The data recorded were visually inspected off-line and only noise free data were included for analysis (Raghuraj, Ramakrishnan, Nagendra, & Telles, 1998). The R waves were "identified" and used to obtain a point event series of successive R-R intervals, from which the beat to beat heart rate series was computed.

Skin conductance level was recorded using Ag/AgCl disk electrodes with electrode gel, placed in contact with the volar surfaces of the distal phalanges of the index and middle fingers of the left hand. A low-level DC preamplifier was used and a constant voltage of 0.5V was passed between the electrodes. Respiration was recorded using a nasal thermistor attached to the more patent nostril. Finger plethysmogram was recorded placing the photoplethysmograph on the volar surface of the distal phalanx of the index finger of the right hand.

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Guided relaxation technique

The guided relaxation technique lasts for 10 minutes and is done in 5 phases of step-wise relaxation, detailed below (Nagendra & Nagarathna, 1988). (i) Relaxing from the tip of the toes to the waist, mentioning each part of the body specifically, followed by chanting the syllable 'A', the first part of the syllable 'Om' (Chinmayananda, 1984), (ii) relaxing from the waist to the neck, followed by chanting the syllable 'U', the middle part of 'Om'. (iii) Relaxing the head and neck, followed by chanting 'M', the last part of 'Om'. (iv) Letting the body `collapse' on the ground with a feeling of 'letting go', chanting AUM. (v) Allowing oneself to feel apart from one's physical body with a feeling of expansion by merging with a limitless expanse such as the sky or ocean. This is practiced slowly and with instructions about relaxation and awareness of physical and mental sensations. Throughout the practice the eyes are closed.

Supine rest

During supine rest, the subject lies supine with the legs apart, arms away from the sides of the body, and eyes closed. This session lasts 10 minutes, as for guided relaxation. In traditional yoga practice, all yoga postures are meant to be practiced with relaxation (i.e., not contracting muscles during the posture) and with a mental state which is calm and 'expanded'. To reach the latter state, the subject initially visualizes a limitless expanse such as the sky or the ocean. While this is true for all yoga postures (e.g., those practiced while standing or seated), it is especially true for shavasana (the supine rest posture). Hence subjects could be expected to anticipate feeling relaxed in this posture.

Data extraction

The end expiratory points of the respirogram obtained from Benedict-Roth apparatus were joined as a slanting line, the slope of which gave the difference between initial and final volumes of oxygen in the tank in a given period, which was approximately 3-4 minutes in most cases.

The following data were extracted from the polygraph records: the breath rate (in cycles per minute) was calculated by counting the breath cycles in 60 second epochs, continuously. The skin conductance level (in micro siemens) and finger plethysmogram amplitude (in mm) were sampled at 20 second intervals. Values averaged across each of the periods (before, test, after) of a session, were used for analysis.

Frequency domain analysis of heart rate variability data was carried out for the 5-minute recordings Before, During the Test period (During 1 and 2) and After the sessions. The mean heart rate was obtained from this record. The mean values were removed from the heart rate series to obtain the heart rate variability values. The heart rate variability power spectrum was obtained using Fast Fourier Transform. The power in heart rate variability series in the following specific frequency bands was studied, viz., the very low frequency band (0 - 0.05 Hz), low frequency (LF) band (0.05 - 0.15 Hz), and high frequency (HF) band (0.15 - 0.50 Hz). The low frequency and high frequency values were expressed as normalized units, which represent the relative value of each power component in proportion to the total power minus VLF component (LF norm = LF/(total power-VLF) X100; HF norm = HF/(total power-VLF) X100) (Task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

ANALYSIS

The t-test for paired data was used to assess the significance between Before values and those recorded During (During 1, During 2) and After. In the case of oxygen consumption and breath volume, comparisons were between Before and After values.

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The Wilcoxon paired signed ranks test was used to study changes in LF/HF, for subjects with baseline LF/HF >0.5 (Group I) and for those with baseline LF/HF £ 0.5 (Group II), separately

RESULTS

The group means (± *SEMs*) obtained in the two sessions are given in Tables 1 and 2.

Oxygen consumption, breath volume

The paired t-test showed a 25.2% decrease in oxygen consumption after guided relaxation ($p<.001$). Breath amplitude increased by 15.0%, after guided relaxation ($p<.01$).

Autonomic measures and breath rate

The paired t-test showed significant differences during guided relaxation compared to the respective Before values for the following parameters, (i) skin conductance level reduced by 35.6%, ($p<.05$);

TABLE 1

Means and Standards error of the means (SEMs) of Oxygen Consumption and Breath volume before and after guided relaxation and supine rest (n = 25)

VARIABLES	GUIDED RELAXATION				SUPINE REST			
	Pre		Post		Pre		Post	
	M	*SEM*	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*
1. Oxygen Consumption (ml/min)	768.8	55.1	574.9†	42.5	618.1	66.3	573.4	58.7
2. Breath Volume (ml)	906.2	57.0	1042.3*	59.0	949.7	59.2	1009.9	64.2

**p<.02, † p<.01, paired t -test, "After" compared to "Before"*

TABLE 2

Subjects with base line ratio of > 0.5				Subjects with base line ratio of < 0.5			
Guided Relaxation		Supine Rest		Guided Relaxation		Supine Rest	
Before	After	Before	After	Before	After	Before	After
.73	.24	.54	.83	.47	1.27	.41	.44
.60	.38	.68	.52	.49	.55	.49	.36
3.17	.54	.77	1.47	.48	.59	.30	.38
.82	.24	.72	.68	.41	.33	.32	.30
.76	.47	.59	.26	.44	.42	.46	.43
.94	.40	.65	.64	.50	.22	.34	.52
.51	.50	.73	.57			.50	.32
.61	.42	.69	.46				
.53	.78						

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(ii) heart rate reduced by 9.7%, (p<.001); (iii) low frequency component reduced by 15.5%, (p<.05), (iv) high frequency component increased by 9.8%, (p<.05). During supine rest compared to the preceding period significant changes occurred in: (i) skin conductance level reduced by 27.0%, (p<.01); (ii) heart rate decreased by 6.5%, (p<.01), also finger plethysmogram amplitude reduced by 25.8%, After supine rest compared to Before (p<.01).

The Wilcoxon paired signed ranks test showed a significant decrease in the LF/HF ratio after guided relaxation, for subjects with baseline LF/HF >0.5 (Group I) (p<.05(1); n=9).

DISCUSSION

The reduction in heart rate and skin conductance levels during both guided relaxation and supine rest, are similar to another report of physiological relaxation during supine rest and guided relaxation (Bera, Gore, & Oak, 1998). The changes in the HF power values suggest that during guided relaxation, cardiac vagal activity is increased (Hayano, Taylor, Yamada, Mukai, Hori, Asakawa, Yokoyama, Watanabe, Takata , & Fujinami, 1993). A decrease in finger plethysmogram amplitude is suggestive of increased peripheral vasoconstriction related to increased sympathetic vasomotor tone (Delius & Kellerova, 1971), which occurred after supine rest, as the After recording was made while seated erect, compared to the supine position, during the Test period. The fact that the same change did not follow the Test period for guided relaxation may be attributed to decreased sympathetic tone after guided relaxation. This decrease in sympathetic tone may be speculated to reduce the magnitude of reflex augmentation in sympathetic activity occurring as a reflex postural readjustment. The change in posture from sitting to supine may also explain the decrease in the low frequency power during supine rest as compared to before. Hence the decrease in the power of the low frequency component during guided relaxation, may also, in part be due to the change in posture. Hence the change in posture in three states, i.e., Before (sitting), During (supine), and After (sitting), also makes it difficult to interpret the results, conclusively. The decrease in oxygen consumption and increase in breath amplitude following guided relaxation suggest that this practice reduces physiological arousal as has been found during Transcendental Meditation (Wallace, 1970; Wallace, Benson, & Wilson, 1971).

When the subjects were subdivided based on their baseline LF /HF ratio (LF/HF > 0.5 or LF/HF < 0.5) which suggested higher or lower sympathetic activity, respectively, (Malliani et al., 1991), a significant difference was found in the changes after guided relaxation and supine rest. Following guided relaxation subjects with baseline LF /HF > 0.5 showed a significant decrease in the LF /HF ratio, whereas the same subjects showed no change after supine rest. Also, subjects with LF /HF < 0.5 at baseline showed no change in this ratio after guided relaxation. This suggests that the practice of guided relaxation may be most effective in reducing sympathetic tone in subjects with higher levels at base line.

In summary, both guided relaxation and supine rest reduce physiological arousal, with changes in a larger number of autonomic measures following guided relaxation. The findings are limited by factors such as the fact the two types of measurements (oxygen consumption and autonomic) were not recorded in all subjects; also the guided relaxation technique has a number of components (muscle relaxation, imagery etc.), which makes it difficult to understand which component influences the result). However, in spite of these limitations the results suggest that instructions to relax (as in guided relaxation) do facilitate relaxation even in subjects who are trained through yoga practice to be able to relax without external instructions. Hence the relaxation effects of yoga practice would be expected to be augmented by guiding instructions.

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OXYGEN CONSUMPTION AND RESPIRATION FOLLOWING TWO YOGA RELAXATION TECHNIQUES

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The present study was conducted to evaluate a statement in ancient yoga texts which suggests that a combination of both "calming" and "stimulating" measures may be especially helpful in reaching a state of mental equilibrium. Two yoga practices, one combining "calming and stimulating" measures (cyclic meditation) and the other, a "calming" technique (shavasan), were compared. The oxygen consumption, breath rate and breath volume, of 40 male volunteers (group mean ± SD, 27.0 ± 5.7 Years) were assessed before and after sessions of cyclic meditation (CM) and before and after sessions of shavasan (SH). The two sessions (CM, SH) were one day apart. Cyclic meditation includes the practice of yoga postures interspersed with periods of supine relaxation. During SH the subject lies in a supine position throughout the practice. There was a significant decrease in the amount of oxygen consumed and in breath rate and an increase in breath volume after both types of sessions (two factor ANOVA, paired t test). However, magnitude of change on all three measures was greater after cyclic meditation. (i) Oxygen consumption decreased 32.1 % after CM compared with 10.1% after SH; (ii) breath rate decreased 18.0% after CM and 15.2% after SH; and (iii) breath volume increased 28.8% after CM and 15.9% after SH. These results support the idea that a combination of yoga postures interspersed with relaxation reduces arousal more than relaxation alone does.

Key words: *yoga; exercise; relaxation; oxygen consumption; respiration.*

INTRODUCTION

Yoga is an ancient Indian science and way of life which includes the practice of specific postures, regulated breathing, and meditation (Taimini, 1961). By practicing yoga a person is supposed to reach a state of mental equanimity, so that responses to favorable or unfavorable external events are well under the individual's control and responses are moderate in intensity. Transcendental Meditation is adapted from ancient yoga texts and involves a daily 20-minute session during which an individual sits with eyes closed and repeats a *mantram* (a phrase or string of words) silently (Maharishi Mahesh Yogi, 1972). Repeated practice is supposed to ultimately help in reaching a state of perfect self-awareness or 'transcendence'. Twenty minutes of transcendental meditation reduced oxygen consumption by 17 percent (Wallace, Benson, & Wilson, 1971). This was believed to be due to reduced mental arousal and reduced muscular activity. Similarly, a 15 percent decrease in oxygen consumption followed meditation on a meaningful syllable (Telles, Nagarathna, & Nagendra, 1995). In contrast, two studies on a single subject practicing yoga breathing (*ujjayi pranayama*) reported increases in oxygen consumption by 19% and 9% , respectively during the practice (Miles, 1964; Rao, 1968). More recent studies on groups of yoga trainees showed that other yoga breathing practices also increased oxygen consumption by an average of 28 percent following a month of practice (Telles, Nagarathna & Nagendra, 1994) and by an average of 17 percent as an immediate effect of 45 minutes of practice (Telles, Nagarathna & Nagendra, 1996). The metabolic rate increased, both during a sitting (Rai & Ram, 1993) and a standing yoga posture (Rai, Ram, Kant, Madan,

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& Sharma, 1994), when these postures were compared with supine rest and with sitting in a chair. In particular, the standing yoga posture, virasan, induces a hypermetabolic state with increased sympathetic activity, with these disappearing with the subject adopting a supine posture (shavasan). These differences in reported levels of oxygen consumption were probably related to the use of differing types of yoga practices. In general, oxygen consumption decreased following meditation and increased during or after yoga breathing practices and postures. This observation may be explained by the fact that meditation reduces muscular effort, while yoga breathing and yoga postures, though practiced with relaxation, may increase muscular effort, relative to meditation. These findings are in line with known reports that lowered muscular effort is associated with reduced metabolic rate. The results also suggest that though all yoga practices are supposed to increase mental relaxation, the metabolism lowering effect is better following meditation, which may be associated with greater mental calmness compared with yoga postures or breathing. On the other hand, it is worth noting that traditional yoga texts say that it may also sometimes be desirable to activate the mind (Chinmayananda, 1984): "In a state of mental inactivity awaken the mind; when agitated, calm it; between these two states realize the possible abilities of the mind. If the mind has reached the state of perfect equilibrium then do not disturb it again". For most persons, the mental state while doing routine activities (not necessarily associated with yoga), is neither "inactive" nor is it "agitated", but is somewhere between these extremes, and hence a combination of "awakening" and "calming" measures may be better suited, to reach a balanced, relaxed state.

The foregoing idea, drawn from the traditional texts, was the basis for a yoga practice called '*cyclic meditation*'. This technique includes the practice of four yoga postures interspersed with relaxation while supine, thus achieving a combination of both "stimulating" and "calming" practices (Nagendra & Nagarathna, 1997). In the activating phase, the yoga postures are practiced about four times slower than that required by classical descriptions. This slower practice requires more effort than the usual practice. We hypothesized that because cyclic meditation (CM) has repetitive cycles of 'activating' and 'calming' practices, based on the idea from the ancient texts, as discussed earlier, practicing CM would cause greater relaxation compared with supine rest in shavasan (SH). The present study was designed to compare the oxygen consumption and respiration after the practice of CM, with the same measurements made after a period of the equal duration of supine rest. In this way, we objectively sought to evaluate the CM technique based on ancient texts.

MATERIALS AND METHODS

Subjects

There were 40 male volunteers with ages between 20 and 47 years (group mean ± SD, 27.0 ± 5.7 years). The oxygen consumption, breath rate, and breath volume have been shown to vary with th phases of the menstrual cycle, both at baseline (Das & Jana, 1991) and in the response following exercise (Matsuo, Saitoh & Suzuki,1999), hence we included only male volunteers in teh study. All subjects were in normal health, based on a routine clinical examination, and none of them had a history of smoking or of respiratory ailments. They had been practicing yoga, including both *cyclic meditation* and relaxation in a supine position (*shavasan* = corpse posture) for periods varying from 3 to 72 months (group mean ± SD, 32.9 ± 19.8 months). None of the volunteers were taking any medication (allopathi, ayurvedic or home remedies) and did not use any other wellness strategy. The subjects were told that the study intended to study the physiological effects of *cyclic meditation* and of *shavasan*. Their informed consent was obtained.

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DESIGN OF THE STUDY

Subjects were assessed in two types of sessions, namely CM and SH. For half the subjects the CM session took place on the first day, with SH the next day. The other subjects had the order of the sessions reversed. Subjects were alternately allocated to either schedule, to remove any contribution of a retest effect to results following the two sessions. Assesment were made before and after the practice. but not during them. In general. Subjects were told that the experiment aimed at comparing the effects of the two yoga practices. The aim of the experiment (i.e.,whether a combination of activation and relaxation, in CM, as compared with relaxation alone, in SH would alter the metabolic and breath rates in the same or different directions)was not explained to them.

During recordings, subjects were asked to sit erect in the chair, with no specific in structions about breathing except that they were to breath as normally as possible.

Recording procedure

Oxygen consumption was recorded with a closed-circuit Benedict-Roth apparatus (INCO, Ambala, India) using the standard method (Mountcastle, 1980). The subject breathed into an oxygen tank from which exhaled carbon dioxide was excluded by absorption in sodium hydroxide. The subjects were asked to breathe into a mask, which covered their nose and mouth but were not given specific instructions about breathing except that they were to breathe as normally as possible.

Data extraction and analysis

The end expiratory points of the respirogram were joined as a slanting line, the slope of which gave the difference between initial and final volumes of oxygen in the tank in a given period, which was approximately 5 minutes in most cases. The breathing rate and respiratory (tidal breathing) volume were also obtained from the record. The height of the respiratory wave (in mm) was converted to volume (in ml), based on the calibration of the apparatus, i.e., 10 mm = 100 ml. The minute ventilation was calculated as the product of respiratory rate and breath voulme. The values of oxygen consumed (in ml/min) were converted to ml/min Standard Temperature and Pressure Dry (STPD), according to the accepted method (International Union of Physiological Sciences Commission, 1991).

The data were analyzed using 2-factor analysis of variance (ANOVA), the Tukey test for multiple comparisons of mean values, and the paired t test (to compare before and after values). The ANOVA was used to determine if there was a significant difference between sessions (factor A) and between assessments made before and after the sessions (Factor B). Pearson correlation coefficient was used to correlate percentage change after both CM and SH session in (1) oxygen consumption, (2) respiratory rate, and (3) breath volume, with (1) experience in yoga (2) experience in CM and (3) *experience in* SH.

Cyclic meditation

Cyclic meditation lasted for 22 minutes 30 seconds. Throughout the practice the eyes were closed and subjects followed instructions on an audio tape, to carry on the practice slowly, with awareness and relaxation. The practice began by repeating a verse from teh yoga text (40s); followed by isometric contraction of the muscles of the body ending with supine rest (1 min) standing at ease (called tadasana) and 'balancing' the weight on both feet (2 min); then the first actual posture. bending to rhe right (*ardhachakrasana,* 1 min 20 s); a gap of 1 min 10 s with instructions about

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relaxation and awareness; bending to the left (1 min 20 s) ; a gap as before (1 min 10 s); forward bending (padahastasana, 1 min 20 s) ; another gap (1 min 10 s); a gap as before (1 min 10 s); forward bending (Padhastasana, 1 min 20 s); another gap (1 min 10 s); backward bending (ardhacakrasana, 1 min 20s); supine rest with instructions to relax the body in sequence (10 min). The postures were practiced slowly, with awareness of all the sensations that are felt. This slower practice required greater effort than usual. This grater effort was both physical (to do an action slowly) and mental (to resist completing the physical activity with the usual speed, a process with prevented the thought from 'wandering' and incresed teh awareness of the self).

Shavasan

During SH, or the corpse posture, the subject lay supine with legs apart and arms away from the sides of the body and eyes closed. This practice lasted 22 min. 30 sec., so that the duration was the same as for CM.

RESULTS

The group mean values and Standard Error of the Mean (SEM) for oxygen consumption, breath rate, and breath volume are given in Table I.

Two factor ANOVA

There was a significant difference between values recorded before and after the sessions of CM and of SH (i.e., Factor B) for: (i) oxygen consumption ($F = 8.38$, for $DF = 1,156$, $p<.001$), (ii) breath rate ($F = 12.70$, DF as above, $p<.001$), and (iii) breath volume ($F = 15.82$, DF as above, $p<.001$). There was no significant change in minute ventilation ($P>.05$). The difference between assessments made after and before the sessions was not significant (Factor A), with no significant interaction between Factors (A X B).

Table 1. Oxygen consumption and respiratory measures pre and post cyclic meditation and shavasan[a]

		Cyclic meditation	Shavasan (supine rest)
Oxygen consumption (ml/min)	Pre	882.1 ± 76.5	797.2 ± 63.6
	Post	599.0 ± 47.1^{++}	716.6 ± 60.1
Breath rate (cpm)	Pre	12.9 ± 0.8	12.5 ± 0.9
	Post	9.3 ± 0.7^{*++}	10.6 ± 0.8 $^{++}$
Breath Volume (ml)	Pre	922.9 ± 40.8	1014.8 ± 56.0
	Post	1189.2 ± 57.9 $^{**++}$	1175.8 ± 58.2 $^{++}$
Minute ventilation (ml /min)	Pre	11724 ± 4062	11440 ± 3821
	Post	11439 ± 3794	10251 ± 3999^{+}

[a]Values are group mean ± SEM

$^{*}p < .01$, $^{**}p < .005$ Tukey test, post compared to pre.

$^{+}p < .05$, $^{++}p < .001$, t test for paired data, post compared to pre.

(F = 15.82, DF as ab ove, p<.001). There was no significant change in minute ventilation (p> .05). the difference between values of the two types of sessions (i.e., CM, SH) were not significantly different (Factor A), with no significant interaction between Factors (A x B).

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Tukey multiple comparison test

The average respiratory rate recorded after *cyclic meditation* was significantly lower than the average value recorded before ($q = 4.65$, $p<.01$). The respiratory amplitude, in contrast was significantly higher after *cyclic meditation* compared to before ($q = 4.95$, $p<.005$).

Paired t test

The oxygen consumption decreased significantly after *cyclic meditation* (32.1%, $p<.001$) and *shavasan* (10.1%, $p<.05$). Also, the breath rate was significantly lower after both sessions: after *cyclic meditation* a decrease of 3.6 cycles per minute ($p<.001$), and after *shavasan* a reduction of 1.9 cycles per minute ($p<.001$). In contrast, the breath amplitude, which is related to the depth of breathing, was significantly higher after both types of sessions: after *cyclic meditation* an increase of 28.8% ($p<.001$) and after *shavasan* an increase of 15.9% ($p<.001$). Minute ventilation decreased by 10.44% after SH($p<.05$).

Pearson correlation coefficient

There was no significant correlation between percentage change after both CM and SH sessions, in (1) oxygen consumptions, (2) respiratory rate, and (3) breath volume. with (1) experience in youga

DISCUSSION

There was a significant decrease in oxygen consumption and breath rate after both cyclic meditation (a technique which included yoga postures interspersed with periods of supine rest) and after SH (supine rest alone). The breath volume was raised after both practices. The magnitude of change for all three parameters was greater after cyclic meditation and did not vary with the duration of experience of shavasan and of cyclic meditation, though there was a wide range in this experience among the subjects (i.e., from 3 to 72 months).

The breath rate. depth, and breath phase duration(inspiration/expiration)are all highly sensitive to phasic changes in the psychological state(Lorig & Schwartz. 1990). Theoretical models of pulmonary response have tended to identify a single variable, typically the metabolic rate, and to attribute the majority of changes in pulmonary response to that variable. For example, early studies on Transcendetal Meditation reported that the observed feduction in metabolic rate (and hence in the need of oxygen) during meditation was reflected in adecrease, essentialaly involuntary. in the rate of respiration and in the volume of air breathed (Wallac & Benson, 1972). The greater decreased in oxygen consumption, decrease in breath rate, and absence of change in minute ventilation on spite of the greater breath volume) after CM, may have a similar explanation.

The greater reduction in oxygen consumption after CM and the changes in respiration suggested that in spite of the practice of yoga postures, which may be expected to be more stimulating than supine rest is, the effect suggested relaxation. These findings were opposite to a previously reported increase in oxygen consumption following virasana, a standing yoga posture (Rai & Ram, 1993). This standing yoga posture induces a hypermetabolic state with increased sympathetic activity, which disappears when the subjects adopts a supine posture (SH). The present results also suggest that while practicing yoga postures for relaxation, two factors are important, maintaining a relaxed mental attitude and having periods of rest (no activity) following a period of activity.

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The importance of interspersing exercise with periods of rest has already been described (Falk, 1995). Intermittent exercise was described as more likely to enhance enjoyment and improve compliance with the exercise plan. Yoga postures have been shown to serve as a form of mild exercise (Rai & Ram, 1993). The yoga postures practiced in CM may not have served as a form of exercise, through possivly of smaller magnitude , has not been evaluated. However, it as been shown that another mind-modyfying Oriental practice, Tai Chi, which has been described as a 'moving meditation,' caused changes in heart rate, blood pressure, and urinary catecholamines, which were similar to walking at speed of 6Km/ hour(Jin, 1992). Because the stress reducing effort effects of noncompetitive, moderate exercise are well known (Shephard, 1997), we may indirectly infer that the relatively higher level of physical activity in CM as compared to SH, may explain the greater respiratory changes following CM.

During CM, subjects are given instructions to relax and maintain that mental state. It has already been shown that exercise plus cognitive strategy programs are more effective in promoting psychological benefits than are exercise programs lacking a structured cognitive component (Brown et al., 1995). Hence both cognitive and physiological factors may contribute to the greater reduction in oxygen and other respiratoy changes following CM as compared with supine rest.

In summary, the findings support the idea that CM, which combines "stimulating" and "calming" techniques, practiced with a background of relaxation and awareness may reduce physiological arousal better than SH can (which is calming). However, the present results require to be substantiated with added controls (e.g., studying the effect of no practice and of postures alone.

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YOGA BASED ISOMETRIC RELAXATION VERSUS SUPINE REST: A STUDY OF OXYGEN CONSUMPTION, BREATH RATE AND VOLUME AND AUTONOMIC MEASURES

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Forty male volunteers with ages ranging from 16 to 46 yrs ware studied in two sessions, yoga based isometric relaxation technique (IRT) and supine rest (SR). Assessments of autonomic parameters were made in 15 subjects, before and after the practices, whereas oxygen consumption, breath rate and breath volume were recorded in 25 subjects, before and after IRT and SR. A significant decrease in breath rate after IRT and in linger Plethysmogram was recorded after SR. The results suggest possibilities for IRT in reducing some physiological signs of anxiety.

Various conventional as well as non-pharmacological methods of relaxation, including autogenic muscle relaxation are becoming popular for reduction of stress (De Berry, Davis & Reinhard, 1939). Traditional yoga texts say that it may also sometimes be desirable to activate the mind (Chinmayananda, 1984): "In a state of oblivion awaken the mind again; when agitated, pacify it; in between understand that the mind is full of potency. If the mind has reached the state of perfect equilibrium then do not disturb it again" (p. 275). For most persons routinely, the mental state is neither in a "state of oblivion" nor is it "agitated", but is somewhere between these extremes, and hence a combination of "awakening" and "pacifying" measures may be better suited, to reach a state of equilibrium. Once the mind is out of *vikshipta* (a state of unsteadiness), then the equanimity will set in. To shatter the 'Laya' (a state of oblivion) and pacify the *vikshipta,* a combination of stimulation and relaxation may be a better measure.

Isometric squeeze relaxation (a variant of progressive relaxation) may be more appropriate for individuals who have difficulty focusing, while meditation may be better suited to those who already possess well-developed relaxation skills at the trait level (Weinstein & Smith, 1992). It is important that the appropriate relaxation technique is used, as people with mental illness may experience an exacerbation of their symptoms with the injudicious use of relaxation techniques that use imagery (Harding, 1996). There are some relaxation methods, which can be carried out as a simple technique "on the spot" like the intervention in the present study (Payne, 1 995).

The objective of the present investigation was to evaluate the efficacy of yoga based isometric relaxation technique (a variant of conventional technique), with external instructions to reduce psychophysiological arousal. This is basically a combination of isometric contractions of all Muscle groups followed by relaxation with breath awareness (Isometr*ic relaxation technique,* IRT). For comparison. assessments were also made following *supine rest (SR).*

METHOD

Subjects

The subjects were 40 male volunteers, with ages ranging from 16- 46 years and with an average of 23.9 months of experience of yoga practice. The autonomic parameters were assessed in 15 subjects (group's average age was 30.2, *SD* = 6.1 yr.). In 25 subjects the oxygen consumption, breath rate and volume were measured before and after the two practices (group's average age was 28.2, *SD* = 6.6 yr,).

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Design

Subjects were studied in two separate relaxation sessions, viz., isometric relaxation technique (IRT), and supine rest (SR) with instructions as a control. The two sessions were on different days, at the same time of the day. For half the subjects, alternately, the IRT session was on the first day with the SR session the next time. The order was reversed for the remaining subjects. Each recording session was of 10 minutes and consisted of 2 periods, viz., before (5 minutes) and after (5 minutes The subjects were sitting at case before and after the practice periods, and supine during the relaxation periods. Both techniques were of 10 minutes duration under the same standard conditions.

Assessment

The oxygen consumption was recorded with a closed circuit, Benedict-Roth apparatus (INCO, Ambala, India) using the standard method (Mountcastle, 1980). The subject breathed into an oxygen tank, from which exhaled carbon dioxide was excluded by absorption in sodium hydroxide. The subjects were asked to breathe into the mask, which covered their nose and mouth. Recordings were made before and after, but not during test periods.

A 4-channel polygraph (Medicaid Systems, Chandigarh, India) was used to record the electrocardiogram (EKG), respiration, and finger plethysmogram amplitude EKG was recorded using standard Limb lead 1 configuration. The EKG was digitized using a 12 bit analog-to-digital convertor (ADC) at a sampling rate of 500 Hz. The data recorded were visually inspected off-line and only noise free data were included for analysis (Raghuraj, Ramakrishnan, Nagendra & Telles, 1998). The R waves were detected to obtain a point event series of successive R-R intervals, from which the beat to beat heart rate series was computed.

Respiration was recorded from using a nasal thermistor attached to the more patent nostril. Finger plethysmogram amplitude was recorded placing the photoplethysmograph on the volar surface of the distal phalanx of the index finger of the right hand.

Isometric relaxation technique (IRT)

The isometric relaxation technique lasts for 10 minutes and is done in 5 phases of step-wise relaxation, detailed below (Nagendra & Nagarathna, 1988). (i) Isometric contractions of all the muscle groups from the toes to the facial muscles, mentioning each part of the body specifically, (ii) letting the body collapse' on the ground with a feeling of 'letting go', till the changes revert back to normal, (iii) Watching the abdominal movements, (iv) synchronizing the abdominal movements with breath, (v) developing the breath awareness followed by invoking the positive emotions with the breath 'This is practiced slowly and with instructions about relaxation and awareness of breath and mental sensations. Throughout the practice the eyes are closed.

Supine rest (SR)

During SA, the subject lies supine with the legs apart, arms away from the sides of the body, and eyes closed. This session lasts 1 0 minutes, as for IRT.

Data extraction

The end expiratory points of the respirogram obtained using the Benedict-Roth apparatus were joined as a slanting line, the slope of which gave the difference between initial and final volumes of oxygen in the tank in a given period, which was approximately 3-4 minutes in most cases. The breath rate and respiratory (tidal breathing) volume were also obtained from the record.

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The following data were extracted from the polygraph records: The respiratory rate (in cycles per minute) was calculated by counting the breath cycles in 60 second epochs, continuously. Finger plethysmogram amplitude (in mm) was sampled at 20-second intervals. Values averaged across each of the periods (before, after) of a session, were used for analysis.

Frequency domain analysis of heart rate variability (HRV) data was carried out for the 5-minute recordings before and after the sessions. The mean heart rate was obtained from this record. The mean values were removed from the heart rate series to obtain the HRV values. The HRV power spectrum was obtained using Fast Fourier Transform (FFT). The power in HRV series in the following specific frequency bands was studied, Viz., the very low frequency (VLF) band (0- 0.05 HZ), low frequency (LF) band (0.05- 0.15 HZ), and high frequency (HF) band (0.15- 0.50 Hz). The low frequency and high frequency values were expressed as normalized units, which represent the relative value of each power component in proportion to the total power minus VLF component (LF) norm = LF/ (total power-VLF) X 100; HF norm = HF/(total power-VLF) X 100)' (Task force of the European Society of Cardiology the North American Society of Pacing and Electrophysiology, 1996).

Data analysis

A two factor analysis of variance (ANOVA) was used to check for significant differences between the categories of subjects, i.e., factor A, and for differences between recordings before and after, i. e., factor B. The Tukey test for the least significant difference between means was used for multiple comparisons. The 't' test for paired data was used to assess the significance between, after, and before values of each group, separately, to detect changes which were not significant with the Tukey test.

Oxygen consumption, breath rate and breath volume

There was a significant difference between values recorded before and after the session of isometric relaxation technique and of supine rest (i.e., Factor B) for breath rate $F = 5.22$, for $df = 1,96$, $p<.05(2)$, values for oxygen consumption, breath amplitude were not significant. The difference between two categories of subjects was not significant (Factor A), with no significant interaction between Factors (A X B).

RESULTS .

The group means ± SEMs obtained in the two sessions are given in Tables 1 & 2

Table 1: Means and Standard Error of the Means (SEMs) of Oxygen Consumption, Breath Rate and Breath Volume (n = 25)

Parameters		IRT		SR	
		pre	*post*	*pre*	*post*
Oxygen Consumption (Ml/min)	Mean	846.1	694.8	720.6	670.1
	SEM	84.1	61.4	54.8	68.1
Breath Rate (cpm,)	Mean	11.8	9.4**	11.5	10.2
	SEM	1.0	0.6	1.0	0.7
Breath Volume (ml)	Mean	1079.2	1188.3	986	1052.6
	SEM	68.0	75.1	84.0	75.9

** p<.01 paired t-test. "Post" compared to "Pre"*

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Table 2

Means and Standard Error of the Means (SEMs) of Autonomic Variables (n=15) Before and After Isometric Relaxation and Supine Rest

Parameters		IRT		SR	
		pre	*post*	*pre*	*post*
Heart Rate (bmp)	Mean	76.1	74.8	76.3	75.8
	SEM	2.6	3.0	2.3	2.7
Respiratory Rate (cpm,)	Mean	19.1	17.0*	19.1	18.0
	SEM	0.9	1.2	1.3	1.2
Finger Plethysmogram amplitude(mm)	Mean	3.73	4.05	7.43@	5.27***
	SEM	0.3	0.5	0.8	0.7
Low frequency(in nU)	Mean	35.9	37.4	37.9	40.3
	SEM	2.1	3.9	4.3	3.6
High frequency(in nU)	Mean	64.1	62.6	62.0	59.6
	SEM	2.1	3.9	4.3	3.6
LF/HF ratio	Mean	0.59	0.84	0.76	0.79
	SEM	0.1	0.3	0.2	0.1

**p<0.05 ***p<.001, paired t test. "Post" compared to "Pre"* *@p<.001, Tukey test*

The paired t test showed significant reduction in breath rate (20.6%, p<.01) after IRT, values for oxygen consumption and breath amplitude after both IRT and SR sessions were not significant

Autonomic measures

There was no significant difference between values recorded before and after the session of isometric relaxation techniques and of supine rest (i.e., Factor B) for finger plethysmogram amplitude, heart rate, high frequency in power spectrum low frequency, ratio of low frequency to high frequency (LF/HF). The differences between the two categories of subjects (Factor A) was significant for finger plethysmogram amplitude (F=15.90, df =1.56, p<. 001 (2), with a significant interaction between Factors (A X B) for finger plethysmogram amplitude (F=4.04, for df =1.56, p<. 05(1)).

Tukey multiple comparison test shows that the average finger plethysmogram amplitude recorded before SR as a baseline was significantly more than the average value recorded before IRT (q = 6.0, p<. 001).

The paired t test showed a significant reduction in respiratory rate (10.4%, p<. 05) after IRT and in finger plethysmogram amplitude (29.0%, p<. 01) post SR, compared to the respective 'before' value for these parameters.

DISCUSSION

In the present study there was a significant decrease in breath frequency following IRT, and a decrease in finger plethysmogram amplitude after SR. There were no changes in measures of autonomic activity. The rate of respiration is highly sensitive to phasic changes in the psychological state (Lorig & Schwartz, 1990). The increase in breath rate has been correlated with experimentally evoked fear and anxiety (Ax, 1953), as well as before situations such as parachute jumping (Fenz & Jones, 1972). The reduction in breath rate after yoga based IRT is consistent with other reports of reduced breath rate related to the practice of yoga, both as an immediate effect (Wallace,

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Benson & Wilson, 1971) and after three months (Joseph et al., 1981). This suggests that IRT may help to reduce some aspects of physiological arousal, without modifying autonomic activity.

Similarly, the non-significant trend of decrease in oxygen consumption and increase in breath amplitude after IRT, also suggest a reduction of arousal. A decrease in finger plethysmogram amplitude is suggestive of increased peripheral vasoconstriction related to increased sympathetic vasomotor tone (Delius & Kellerova, 1971), which occurred after SR. This change may be due to the postural readjustment as the 'post' recording was made while seated erect, compared to the supine position, during the test period.

In conclusion, yoga based IRT produced better physiological rest than SR, supporting the idea that a combination of stimulation (through isometric contractions) and relaxation may reduce arousal better than relaxation alone.

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PHYSIOLOGY OF PRANAYAMA

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OXYGEN CONSUMPTION DURING PRANAYAMIC TYPE OF VERY SLOW-RATE BREATHING

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To determine whether the yogic *Ujjayi* pranayamic type of breathing that involves sensory awareness and consciously controlled, extremely slow-rate breathing including at least a period of end-inspiration breath holding in each respiratory cycle would alter oxygen consumption or not, ten males with long standing experience in *pranayama,* and volunteering to participate in the laboratory study were assessed. These subjects aged 28-59 years, had normal health appropriate to their age. Since Ku*mbhak* (timed breath holding) is considered as an important phase of the respiratory cycle in the *pranayama,* they were categorised into two groups of five each, one group practising the short *Kumbhak* varieties of *pranayama, and* the other the long *Kumbhak* varieties of *pranayama.* The duration of *Kumbhak* phase was on an average 22.2 per cent of the respiratory cycle in the short *Kumbhak* group and 50.4 per cent in the long *Kumbhak* group. The oxygen consumption was measured in test sessions using the closed circuit method of breathing oxygen through the Benedict-Roth spirometer. Each subject was tested in several repeat sessions. Values of oxygen consumption of the period of pranayamic breathing, and of post- pranayamic breathing period, were compared to control value of oxygen consumption of the pre- pranayamic breathing period of each test session. The results revealed that the short *Kumbhak* pranayamic breathing caused a statistically significant increase (52%) in the oxygen consumption (and metabolic rate) compared to the pre-pranayamic base-line period of breathing. In contrast to the above, the long *Kumbhak* pranayamic breathing caused a statistically significant lowering (19%) of the oxygen consumption (and metabolic rate). The values returned to near normal in the post-pranayamic periods. The data provide a basis to indicate that different types of pranayamic breathing may lead to different types of alterations in the oxygen consumption and metabolic rate.

The nature of physiological alterations that possibly occur with different types of yogic practices is not well understood. The present study was aimed to determine whether oxygen consumption and metabolism would be altered or not in practitioners of Yoga during the consciously regulated, extremely slow-rate, Ujjayi pranayamic type of timed breathing that includes breath- holding phase *(Kumbhak)* in each cycle of respiration. It was aimed to assess this in two variants of the pranayama that differed in the ratio of duration of the *Kumbhak phase* in the breathing cycle, one being short and the other long.

It was reported in two earlier studies[1,2] involving only one subject in each, that oxygen consumption during *Ujjayi pranayama,* when compared to the preceding period, increased in one of the subjects by +19 per cent and in the other subject by +9 per cent. It is necessary however, to examine more subjects practising *pranayama* to check whether such an impression of increase which is based on the data of only two subjects will be generally valid. Therefore, the present study was undertaken on ten subjects to assess the effects of two pranayamic variants on oxygen consumption of subjects under each variant. Further, it was aimed to obtain data of each subject as averages of several repeat test sessions (over 7) to improve reliability.

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MATERIAL & METHODS

Ten healthy male subjects of the age range of 28-59 years were selected out of the volunteers who responded to our initial contact. A subject was chosen on the following criteria: (i) pranayamic experience of sufficiently long duration, preferably for some years; (ii) normal health appropriate to age and having not suffered from any major illness; and (iii) willingness to attend a large number of test sessions without dropping out. A full explanation about the study was given to each subject and informed consent obtained. The peak flow rates of the subjects were in the normal range (for Indians) of 390-510 1/min, mean and SD being 451 ± 421/ min (determined with Wright's mini peak flow meter).

All subjects had been practising the Ujjayi pranayama with different ratios of the phase durations of the respiratory cycle. In the typical *Ujjayi pranayama* [3,4] the respiratory rate is markedly reduced volitionally and each cycle includes successively (i) the phase of inhalation while the glottis is kept partially closed; (ii) the phase of *Kumbhak* or holding of breath (retention of the inhaled air) during which the glottis is fully closed, and *(iii)* the phase of a steady exhalation. There may also be a phase of end-expiration Kumbhak or breath-holding in exhaled state, before beginning the next cycle. The cycles were repeated regularly while keeping respective durations of the phases similar in all the cycles of the pranayamic breathing. In typical ratio, the expiration phase is twice that of inspiration while the duration of *Kumbhak* in end of inspiration is twice that of expiration phase, i.e., 1:4:2 for inspiration: hold: expiration. However, different types of *Pranayama* differ widely in the ratios of the phase durations. The *Kumbhak* is to be done in ease and not to be prolonged as in breath-holding for breaking point test. During pranayama, the subject is required to become aware of sensations of passage of air through nasal passages and of filling up of lungs. The entire process of breathing is to be executed without stress and strain, under conscious control, maintaining the ratio of phase durations of each cycle of respiration, carrying on rhythmically, steadily and without jerking movements. In the end-inspiration *Kumbhak* phase, the perineal muscles are held in contraction, and chin lowered on to the manubrium of *sternum (mulabandha, and jalandara bandha).* In the end- expiration *Kumbhak* phase, the abdomen is drawn inwards and backwards with diaphragm in raised position *(uddiyan bandha).*

Since the duration of the inspiratory *Kumbhak* is known to be an all-important variable of the *Ujjayi Pranayama,* we have categorised the ten subjects into two groups of five each, viz., long and short *Kumbhak* types. In the long *Kumbhak* group (LK), the *Kumbhak* (in inspiration) phase duration was 50.4±6.6 per cent of the total duration of respiratory cycle. In the short *Kumbhak* group (SK) the *Kumbhak* phase was only about 22.2 ± 10.6 percent of the total cycle duration. The inspiration-Kumbhak-expiration duration's ratio was about 1:4:2 in the long *Kumbhak* group, and about 1:1 (or less):1 in the short, *Kumbhak* group. Three subjects in each group also had the end- expiration Kumbhak. However, there were no differences in other respects, i.e., in the base-line values of the two groups of subjects. Their average ages were not significantly different (Student's 't' test), the values being 45.2 ± 7.4 years for the SK group and 38.4 ± 13.9 years for the LK group. Besides, the pre-pranayamic base-line values of pulmonary ventilation were not different, the value of the SK group was 15.0±5.8 1/min BTPS and of the LK group was 10.3 ± 2.5 l/min. BTPS (Table 1). The base-line oxygen consumption also, of the two groups was not different (Student's 't' test), the average values being 269.6 ± 127 ml/min STPD for the SK group and 320.8±96.7 ml/min STPD for the LK group (Table II).

The oxygen consumption was recorded using the closed circuit method of the Benedict-Roth apparatus[5]. In this method the subject breathes into an oxygen tank, the exhaled carbon dioxide having been excluded from entering the tank by absorbing it in soda lime.

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Table I Pulmonary ventilation (1 /min BTPS)
(Data are mean ± SD)

	Short Kumbhak pranayama				Long Kumbhak pranayama			
Subjects	Replication	Before Pranayama	During Pranayama	After Pranayama	Subjects	Replicatio	Before Pranayama	During Pranayama	After Pranayama
STY	14	15.8 ± 2.8	7.4 ± 1.9	12.8 ± 2.0	NA	13	6.6 ± 2.2	4.5 ± 1.0	6.2 ± 1.4
VIS	10	15.0 ± 3.9	6.9 ± 1.0	14.5 ± 2.6	RJ	12	9.5 ± 2.5	6.2 ± 1.2	10.8 ± 2.5
NAR	12	7.7 ± 2.8	5.3 ± 2.3	7.2 ± 2.3	SW	15	13.7 ± 4.9	4.0 ± 0.8	13.6 ± 4.2
VJ	10	12.9 ± 5.4	8.2 ± 1.1	16.9 ± 6.6	STH	11	11.0 ± 4.3	6.0 ± 0.8	11.2 ± 2.9
AI	7	23.7 ± 6.7	8.3 ± 2.0	22.9 ± 7.3	SN	10	10.7 ± 6.7	2.5 ± 0.7	11.9 ± 2.9
Paired 't' test			P< 0.025	Not significant			10.3 ± 2.8	P < 0.025	Not Significant
Mean ± SD		15.0 ± 5.8	7.2 ± 1.2	14.8 ± 5.7			10.3 ± 2.5	1.6 ± 1.5	10.7 ± 2.7
% of 'bfore'		(100.0%)	(48.0%)	(98.6%)			(100.0%)	(46.6%)	(103.8%)

Difference between 'before' values of the two pranayama types was not significant (Student's 't' teset; P>0.1)

Table II. Oxygen consumption (ml/min STPD) Data are mean ± SD)

	Sort Kumbhak pranayama				Long Kumbhak pranayama			
Subjects	Replication	Before pranayama	During pranayama	After pranayama	Subjects	Replication	Before pranayama	During pranayama	After pranayama
STY	14	255 ± 85.0	405 ± 273.3	330 ± 171.6	NA	13	179 ± 65.2	104 ± 40.3	131 ± 63.8
VIS	10	321 ± 87.9	390 ± 129.2	238 ± 119.0	RJ	12	286 ± 138.7	190 ± 71.9	205 ± 84.9
NAR	12	442 ± 154.9	715 ± 286.7	379 ± 101.0	SW	15	432 ± 224.6	342 ± 132.8	355 ± 121.0
VJ	10	236 ± 67.4	339 ± 58.0	268 ± 179.9	STH	11	325 ± 176.9	310 ± 149.7	373 ± 164.1
AI	7	94 ± 53.4	205 ± 169.0	118 ± 75.0	SN	10	382 ± 100.0	349 ± 84.2	320 ± 120.0
Paired 't' test against 'before'			P<0.05	Not significant				P < 0.05	Not significant
Mean ± SD		269.6 ± 127	4.10 ± 187.4	266.6 ± 99.4			320 ± 96.7	259.0 ± 107.6	276.8 ± 104.4
% of 'before'		(100%)	(152%)	(98.8%)			(100%)	(81%)	(86%)

Difference between 'before' values of the two pranayama types was not significant (Student 't" test; P>0.4)

The difference between the initial and final volumes of oxygen in the tank is the oxygen consumed by the subject in a given period of breathing. In normal tidal type of breathing, the end-expiratory points can be joined into a slanted straight line, and the difference between the two ends of the line gives the value of oxygen consumed. In the present study involving a specialized type of *pranayama* breathing also, the same method is useful if the line is drawn as a best-fitting average connecting the end-expiratory points. The accuracy of this value compared well (90%) against a value obtained by summing the oxygen values calculated separately for individual breaths during the period. When the amplitudes of breaths varied much more, that session was not included in the analysis. Moreover, the value for each individual being the mean of data of several test sessions, even the small errors of individual sessions would get evened out in this study. In each experimental (test) session, oxygen consumption assessments were made for the three periods:

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The pre or before, the during, the post or after *pranayamic* practice, as illustrated in Figs 1 and 2. Each of these test periods was of about 4 min duration. The recording laboratory was air conditioned to about 27^{0}C with relative humidity of 50 per cent. Since the subjects had to wear the face mask and breathe through the valves of the closed circuit apparatus they had not used the nostril manipulations and full chin-lock position. In between the three periods (before, during, and after) a pause or an interruption for 30 sec with breathing air was allowed while replenishing oxygen in the spirometer bell and readjusting the writing pen level. The spirometer record provided the values of tidal volume, respiratory rate and also the oxygen consumption of each of the periods. From these, the volume of gas ventilated was calculated. The oxygen values having been obtained under room temperature and pressure, they were corrected for standard temperature and pressure. Whether a change occurred in oxygen consumed during the test period of pranayama and in the period after pranayama, was assessed by comparing with the control value obtained in

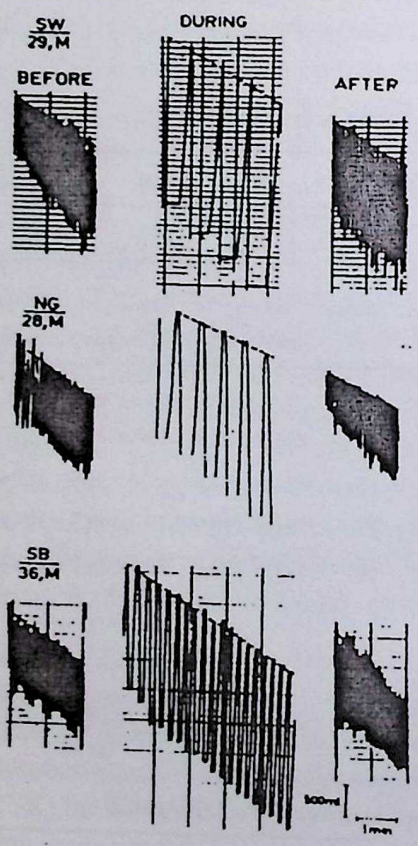

Fig. 1

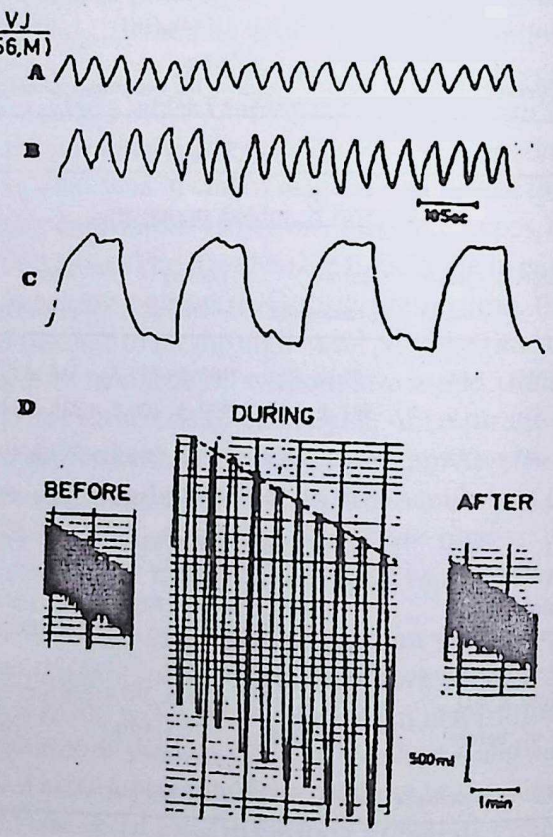

Fig. 2

Fig. 1. Representative record made on a polygraph with mercury strain guage connected to the chest, and subject parallely connected to the Benedict-Roth spirometer while, (A) breathing air with face mask valve opened to outside air, (B) breathing oxygen through the closed circuit system of the spirometer during pre-pranayamic control period, and (C) during the pranayamic practice period (inspiration recorded upwards), (D) records made on the Benedict-Roth spirometer (expiration is upwards), before, during, and after the *pranayama*, this case being of short kumbhak type and having both inspiration and expiratory *kumbhak phases*.

Fig. 2. Examples of short and long *kumbhak* types of *records of pranayamas* on Benedict-Roth spirometer. Pranayama lower two subjects have both inspiratory and expiratory *kumbhak* phases, SB of short type, and NG of long type. (top figure) practices long type with only the inspiratory. *Kumbhak* phase

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the period preceding (before) the pranayama of the same experimental session, so that the status of diet or metabolism and other unknown variables prevailing on that day and time of recording would be common for both control and test data thereby not affecting the inferences. On each subject several test sessions were repeated and the average of these repeated measurements was considered as the value for that subject. Such averaged values of the three test conditions of the five subjects of the group were averaged and treated statistically [6-8]. Statistical significance of difference of oxygen consumption of the pranayamic breathing, or of post-pranayamic period, from the pre-pranayamic value was assessed by the matched pairs 't' test[7,8]. Comparisons across groups were made by Student's 't' test. The significance of effects of the three treatment conditions (before, during, after) for the five subjects of the group were also assessed by the method of analysis of variance[6] i.e., two-way ANOVA.

RESULTS

The short *kumbhak* group (Table II) showed significant increase (52%) of oxygen consumption during the pranayamic practice period over that of pre-pranayamic control value (paired 't' test; $P<0.025$). The value returned to normal in the post-pranayamic period. Out of the total amount of oxygen consumed in the entire experimental session, 43.56 per cent was consumed during the period of pranayamic practice (paired 't' test; $P<0.01$) in contrast to only 27.7 per cent in the pre-pranayamic period, and 28.58 per cent in the post-pranayamic period. ANOVA revealed (Table III) that the effect of treatments was significant ($P<0.01$; 8.7 df 2.8).

TABLE III. Analysis of variance of oxygen amounts consumend

Source	Short Kumbhak pranayama					Long Kumbhak pranayama			
	Df	SS	MS	F	P	SS	MS	F	P
Between subjects	4	213496.7	533374.2	13.7	0.001	20548.4	30137.1	34.8	0.01
Between 'treatments'	2	67900.1	33950.1	8.7	0.01	10120.1	5060.1	5.8	0.03
Residual	8	31112.5	3889.1			6923.2	865.4		
Total	14	312509.3	22322.1			137591.7	9827.9		

The long *kumbhak* group (Table II) showed a significant decrease (19%) in oxygen consumption during the pranayamic practice period from that of pre-pranayamic control value (paired 't' test; $P< 0.05$). Out of the total amount of oxygen consumed in the entire experimental session, 29.4 per cent only was consumed during the pranayamic period in contrast to 36.3 per cent in the pre- pranayamic period, this difference was significant (paired 't'; test, $P < 0.05$). ANOVA (Table III) showed that the treatments effect was significant ($P< 0.03$; F 5.8, df 2.8).

If it is assumed that the respiratory quotient (RQ) is 0.82 and the kcal / 1 oxygen is 4.825, application of the DuBois formula indicates that the metabolic rate in the short *kumbhak* type of pranayamic breathing period will be +70 per cent higher than that of the pre-pranayamic base-line breathing, in contrast to the reduction by -20 per cent in the long *kumbhak* type of pranayamic breathing. Since a variation of RQ between 0.71 and 1.0 contributes to not more than a maximum of 6 per cent error, the above derivations of metabolic rate are reliable enough to understand the effect of Pranayama.

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There was no significant difference between the two groups (Student's 't' test) in the base-line pre- pranayamic pulmonary ventilation (Table 1), or in the base-line oxygen consumption values (Table II). There was a difference (Student's 't' test) only in the base-line respiratory rate, the short *kumbhak* group having 13.1 ± 2.5/ min and the *long kumbhak* group having 7.9 ± 1.61 /min. During *pranayama* the respiratory rate was lowered to 24.42 and 27.84 per cent in the short and long *kumbhak* types, respectively; the corresponding pulmonary ventilatory values were 48 and 46.6 per cent. During post-pranayamic period, pulmonary ventilation was restored to pre- pranayamic levels in both groups.

During both short and long *kumbhak* types of pranayamic breathing periods, the pulmonary ventilation (Table I) was lower than in the pre-pranayamic breathing periods (control values), but interestingly the oxygen consumption (Table II) significantly (paired 't' test) exceeded the pre-pranayamic control value in one type of *pranayama* (SK type), whereas it decreased significantly in the other type of *pranayama* (LK type). Thus the oxygen consumption was not correlated to ventilation, but the duration of *kumbhak* phase on the other hand, seems to play a major role.

DISCUSSION

This type of a detailed and differential study has not been reported previously on the subject of changes of oxygen consumption during the subtypes of *kumbhak*-pranayamic breathing. Miles[1] reported data using the oxygen estimation method similar to the one used in the present research, on a single subject who practised a slow breathing, *kumbhak- pranayama (Ujjayi* type, but time ratios not specified), and also two non-kumbhak types of rapidly (80/min) breathing varieties of *pranayamas,* namely, the *kapalabhati* and *bhastrika.* In the single subject study, all the three types of *Pranayama* caused an increase in oxygen consumption varying from +12 to +35 per cent. Rao[2] also reported data on one subject, showing a 7-9 per cent increase in oxygen consumption during *Ujjayi* type of p*ranayama* having time ratios of 1:4:2. The present results obtained from larger number of subjects differed from those of single subject studies[1,2], since the data revealed for the first time that there could be effects of not only increase but also decrease in oxygen consumption in different sub- types of the *Ujjayi pranayamas.* Hence our study points out the need for a change in the perspective of understanding of effects *of pranayamas.*

The present study offers an indication, on the basis of the data of several test sessions conducted on a larger number of subjects, that the *Ujjayi* types of pranayamic practice could cause either an increase or a decrease in the oxygen consumption, depending on variations in the duration of *kumbhak* or the ratios of durations of different phases of the respiratory cycle.

Although the oxygen consumption was altered during both the pranayamic types, it returned after the *Pranayama* to pre-pranayamic levels. There was no evidence of increased consumption of oxygen following the long *kumbhak pranayama,* thereby indicating that no debt had been incurred during such a *pranayama* or that the low oxygen consumption would have matched to a lowered metabolic state during the long *kumbhak pranayama.* Also, there seems to be no gross lowering of PO_2, or rise of PCO_2, since no effects expected of arterial anoxemia and respiratory chemoreceptor stimulation were apparent as the post-pranayamic ventilation was at the same level as pre-pranayamic level. Contrary trends of oxygen consumption (implying corresponding trends to be occurring in the status of metabolism) observed during the two types of *pranayamas may* be related to the differences in their effects on skeletal muscular relaxation or activity, on variations of autonomic nervous system discharges altering regional blood flows and metabolism, and even on adrenal cortico-medullary secretions. The two types of Pranayamic procedures having

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differing patterns of consciously controlled execution of respiratory rhythms with different time ratios of their phases, and differing in experiences of resulting sensations, could have led to either increase or decrease of arousal or relaxation states and associated shifts in muscular activities and metabolism. The differences in oxygen consumption in the two *pranayamas* may also be partly related to changes in brain blood flow and metabolism due to differences in intensities of regional activities of neurons in the cerebrum under differences in the nature of conscious control of the respiratory rhythm, and in the experiencing of sensations of breathing in the two *pranayamas.*

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ALTERATIONS OF AUDITORY MIDDLE LATENCY EVOKED POTENTIALS DURING YOGIC CONSCIOUSLY REGULATED BREATHING AND ATTENTIVE STATE OF MIND

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Middle latency auditory-evoked potentials (AEP-MLRs) of 10 healthy male subjects in the age range of 21-33 years, were assessed to determine whether yogic pranayamic practice would cause changes in them. The pranayama type assessed here is an exercise of consciously-controlled rhythmic breathing involving timed breath-holding in each cycle of breathing, while the subject holds utmost attention and experiences the touch of inhaled air in the nasal passage. The results revealed that the Na-wave amplitude increased and latency decreased during the period of pranayamic practice, whereas the Pa-wave was not significantly altered. The change is interpreted as an indication of a generalized alteration caused in information processing at the primary thalamo-cortical level during the concentrated mental exercise of inducing modifications in neural mechanisms regulating a different functional system (respiratory). Further researches are required to understand the operational significances of such changes.

Key words: *Middle latency auditory-evoked potential; Yoga; Modifications of neural processin in yoga; Conscious alteration of breathing*

INTRODUCTION

Yogic practices were devised in ancient times to perhaps aid in realising the capability of highest possible functional harmony in body and mind. Pranayamic exercises are among the important yogic practices (Vivekananda, 1973). There are several varieties of pranayamas, some of them (ujjayi, bhastrika variants) require a conscious regulation of the breathing rhythm, maintaining specified ratios of time durations of inspiratory and expiratory phases, as well as timed breath holding in the post-inspiration or post-expiration period, and also holding attention in either imagining the flow of energy along spinal column collaterally with breathing rhythm (Vivekananda, 1973), or in experiencing the sensation of inhaled air touching and passing through the nasal passage (Behanan, 1937), or on concentrating on certain other parts of the body. Since these types of pranayamic practices involve considerable exercising of conscious control processes with precision, a study of evoked potentials in them may reveal some clues of the brain mechanisms underlying such a conscious exercise. Furthermore, since the respiratory rhythm provides an observable indication of the subject being engrossed in the conscious control process, the experimenter can be sure of the subject engaged in the yogic practice during the data acquisition, unlike in subjects doing meditation when no such external indicator will be available to know whether the subject is smoothly continuing in the meditative exercise. For these reasons, we proposed to examine the ujjayi and bhastrika types of pranayama subjects to assess alterations in

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middle latency auditory-evoked potentials (AEP-MLRs). The AEP-MLRs were chosen to begin with, instead somatosensory MLRs to avoid compounding with any sensory-motor potentials produced during the controlled respiratory movements, and to reveal changes of a generalised nature that might be induced by the consciously attentive yogic exercise in the processing of information in a modality other than the somatosensory. The MLRs have been chosen for the study with the premise that conscious processes actively involve several cortical mechanisms and also that corticofugal control processes may exert significant alterations in the processing of information at the brainstem and thalamic levels (Desiraju. 1979, 1984; Steriade and Llinas, 1988; Pribram and McGuiness, 1993, in press).

METHODS

Subjects

10 male subjects with normal hearing and ages ranging from 21 to 33 years (average ± S.D. 25.2 ± 3.2 years) formed the group of pranayama. 10 more male subjects (age 22 to 42 years, mean ± S.D. 31.7 ± 6.8), who had no training in pranayama or in concentration exercise, were also assessed for detecting effects of attention maintained on the nasal air flow and on ongoing tidal respiration that was not controlled consciously. The study was explained to the subjects and their signed informed consent taken.

Before commencement of training in pranayama, each subject of the pranayama group was tested in three sessions conducted usually at several days apart, to assess baseline variations and changes in middle latency auditory-evoked potentials (AEP-MLRs) occurring in successive periods of the 20-min session. In each session of 20 min, a total of four recordings were made during the following time periods while the subject sat awake and relaxed with eyes closed: (i), one recording in the first 5-min period, i.e., in pre-test eyes closed baseline condition (PEC); (ii), two successive recordings in the next 10-min period, i.e., in eyes closed 'control' sitting without pranayama (ECC) and (iii) one recording in the last 5-min period, i.e., in eyes closed post-test condition (ECP). After acquiring data as described above, the subjects were introduced to the training in pranayama practice: 6 of them in the ujjayi type of pranayama, and 4 in the bhastrika type. After practising the pranayama for an average of 21.8 months (range 18-26 months), the subjects were reassessed in test sessions conducted to record the AEP-MLRs in the same temporal sequence of test periods mentioned above, except that the subjects practiced pranayama during the time-period PR, that corresponded in time to the ECC cited above.

Stimulation and recording settings

The AEP-MLRs were recorded from C_z-A_l. In each time-period cited above, 1500 responses in the post-stimulus 70 ms time-period were averaged on a Nicolet (USA) Model Med-80-4 computer system. The preamplifier bandwidth was set at 1-1500 Hz. Click stimuli of 40μs duration, with alternating polarity, were delivered at 5 Hz binaurally through acoustically-shielded ear-phones. The intensity was set at 40 dB above the threshold of hearing, which was about 24 dB under the above mentioned stimulus parameters. It was kept moderate enough so as not to disturb the concentration of subject, and yet be adequate to evoke the potentials with consistency. Subjects were comfortably seated during recording sessions in a dimly lighted (twilight), air-conditioned and sound-attenuated cabin. and were watched throughout via a closed circuit low-light-sensitive television.

Measurements and statistical assessment

Peaking latencies of the waves were measured from the moment of stimulus delivery. Peaking amplitudes of the waves were measured taking the level existing at the time of stimulus delivery

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as the baseline. Averages of the peaking amplitudes and latencies of Na, Pa and Nb waves of the three repeat sessions of a subject were calculated for each time period. Since recordings were made twice in the time period ECC or PR of each of the three sessions. the average of the time period ECC or PR was based on six values. Such averaged values obtained under the conditions of ECC or PR, for the 10 subjects were subjected to the analysis of variance (Snedecor and Cochran, 1967; Zar, 1984) and to the matched pairs t-test, to infer whether significant changes occurred in the peaking of waves during pranayama. Also, the baseline data (of PEC time period) obtained before and after undergoing pranayama training were compared.

Since significant changes are observed for only Na wave, data of Pa wave are presented to only a limited extent, and of Nb wave not detailed in this paper for saving space.

Pranayamic methods

Utmost concentration has to be maintained during the following pranayamas. The subject is asked to concentrate on that point in the nasal passage where the inhaled air is first felt. This training in concentration is claimed to create, in the long run, a steadying effect on the mind (Behanan, 1937). During the pranayama, the subject sits with spine erect. In the ujjayi type of pranayama after a slow but complete exhalation through the left nostril, the next breath is inhaled through both nostrils at a uniform pace, with a partially closed glottis, and the abdominal muscles kept in a state of partial contraction. Inhalation is followed by timed breath-holding (the kumbhak phase), during which both nostrils are closed with the right hand, the glottis is also tightly closed, and the chin is lowered to touch the jugular notch (jalandhar bandha or chin lock). At the end of the kumbhak phase, the head is raised back to the normal level, the glottis is opened partially and the subject exhales through the left nostril, while the abdominal muscles go on contracting. This is followed by a phase of external breath-holding during which the abdominal muscles are specially

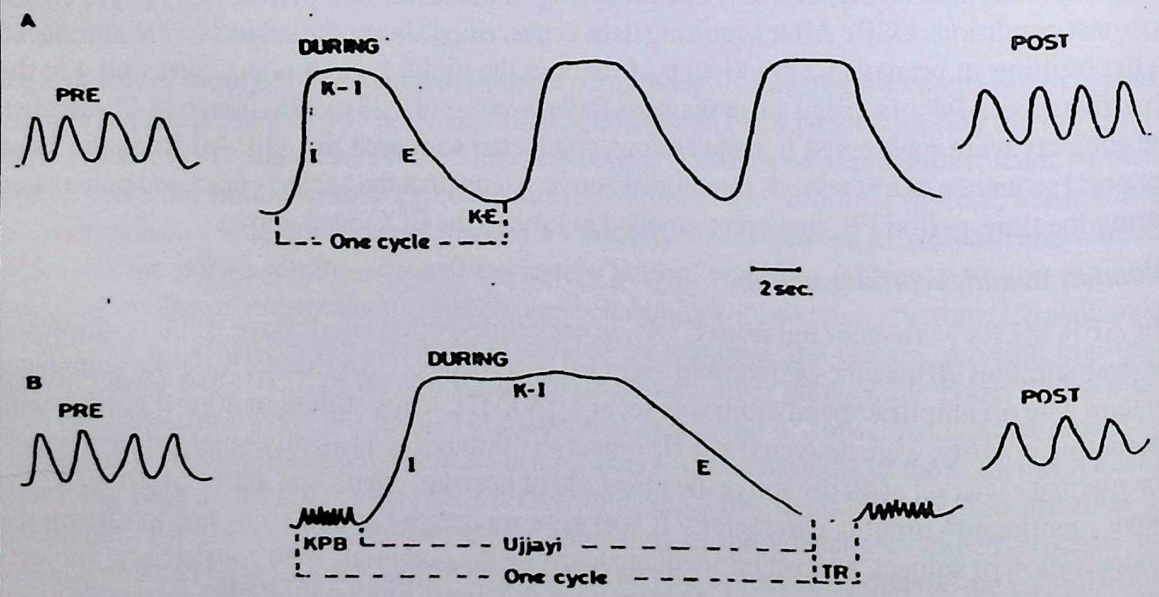

Fig.1 Illustration of typical breathing cycles in 2 types of pranayamas. (A), ujjayi type, during which the duritatio of expiration (E) is typically twice that of inspiration (1), and there is a timed breath-holding at end-inspiration (K-1), and also at end-expiration (K-E). Such cycles of breathing are repeated at about 2/min, (B), bhastrika pranayama, in each cycle of which a cycle of which a cycle of ujjayi type of breathing is preceded by a set of rapid breathing cycles of shallow breaths (KPB). The figure also illustrates for comparison the tidal level of breathing pre and post-pranayamic periods, TR, transition phase between two bhastrika cycles.

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held contracted (uddiyan bandha or abdominal lock). This comprises one cycle of ujjayi which is followed by the next (Fig. 1A). Proficiency is acquired through stages of practice; the first stage involves only inhalation and exhalation in the time (duration) ratio of 1: 2, later on inhalation, timed internal breath holding, and exhalation are practiced in the ratio of 1: 1: 2 and still later on with the ratio of 1: 2: 2. In the last stage, 'external' breath-holding is introduced, so that the ratio becomes 1 : 2:2: 1. Six of the subjects of this study (RMC, RNG, SNT, SK, SKT and VD) had attained this level of accomplishment in the ujjayi pranayama practice. The average durations ± S.D. (in seconds) of the 3 phases, viz., inspiration, 'internal' breath-holding, exhalation, and 'external' breath-holding were 3.9 ± 1.0, 10.0 ± 3.0, 10.4 ± 1.5 and 5.0 ± 1.0, respectively. The average respiratory rate of these six subjects during pranayama was 2.4 ±0.8 cycles/ min. The four remaining subjects (PRJ, SJR, STP and NVR) practiced a modified version of the pranayama (Fig. 1B). In this, each breathing cycle began with exhalation (at the end of tidal breathing), followed by very shallow, rapid breathing at the rate of approximately 2 breaths/s for a total of 5 s, on average. During this part of rapid breathing (which is known as kapalabhati), the amplitude of respiration was usually only 1/5th of the tidal breathing. This is followed by a cycle of ujjayi pranayama, with inhalation, 'internal' breath-holding, and exhalation in the duration ratio of 1: 4:2. There was no phase of 'external' breath-holding. The average durations ± S.D. (in seconds) of these three phases were 5.5 ±0.7, 22.0 ± 2.5, and 8.0 ± 1.5, respectively. During the ujjayi part of the pranayama, the average respiratory rate was 1.6 ± 0.5 cycles/min. This combination of a brief kapalabhati part and a cycle of ujjayi constitutes one unit which is repeated as long as the session lasts. The glottis is kept open during the kapalabhati part, and partially or fully closed during the ujjayi part as cited above. Such a combination pranayama is called the bhastrika type.

The subjects were expected to keep up their proficiency by practising the pranayama daily for about 20 min, except for any occassional lapses.

Their proficiency was checked periodically by a pranayarna expert (teacher) to confirm that the subjects were maintaining their practice.

RESULTS

Evoked potentials were recorded in different periods of the test sessions conducted on subjects before they were initiated into pranayama training-

Peaking latencies and amplitudes of the Na and Pa waves recorded in the subjects before they were trained in pranayama, were not observed to be significantly changing (matched pairs t-test) in the three successive time periods (PEC, ECC, ECP) of a test session (Fig. 2). This check was done to know whether there could be any time effect, or sitting effect, on the evoked potentials recorded in successive time periods of a session. The amplitude of Na wave (mean ± S.D., 10 subjects) was 0.86 ± 0.3 μV in the PEC condition, 0.90 ± 0.44 μV in the ECC condition and 0.81 ± 0.65 μV in the ECP condition; of the Pa wave was 0.66 ± 0.30 μV in the PEC condition, 0.81 ± 0.35 μV in the ECC condition and 0.85 ± 0.45 μV in the ECP condition.

The latencies (meμan ± S.D., 10 subjects) of the 3 waves were as follows: Na wave had 17.2 ± 1.54 ms in PEC state, 16.9 ±1.63 ms in ECC state and 17.0 ± 0.96 ms in ECP state; Pa wave had 26.9 ± 2.12 ms in PEC state, 27.2 ± 2.21 ms in ECC state and 27.2 ± 2.02 ms in ECP state.

Evoked potentials recorded in different periods of pranayama sessions conducted after about 21 months of training and experience in pranayama.

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The Na wave-peaking amplitude (average of 10 subjects) recorded during pranayarna state (PR) was significantly higher (by 108%) than that of the corresponding pretraining period (ECC, Table 1, Fig. 2). The value of post pranayama period (ECP) was not significantly different from that of the pre pranayama period (PEC).

The peaking latency of the Na wave of PR was not different from that of PEC, but was significantly less (by 9%) than that of ECC (Table.11, Fig. 2).

Analysis of variance test showed significant alteration of Na-wave amplitude in pranayama (Table iii), but not so for latency (F(2,27) 2.51, *P*(0.09). Analysis of Na wave peaking amplitudes done separately for ujjayi and bhastrika subjects showed a more significant alteration during ujjayi than during bhastrika compared to pre-pranayama periods with paired t-test (Table III), but ANOVA could not show adequate significance of the alterations probably due to small sample sizes.

The peaking amplitude and latency of the Pa wave were not significantly altered in pranayama compared to the immediately preceding baseline values of PEC state (Tables 1 and II). Their values of the period PR were also not significantly different from those of corresponding periods (ECC) of control sessions conducted before pranayama training. Also there were no significant differences in group averages of the 10 subjects for the 3 waves of PEC periods recorded before the subjects were trained in pranayama and after about 21 months of practice.

TABLE 1

Mean and S.D. of peaking amplitudes (μV) of waves of middle latency auditory-evoked potentials recorded during periods of pranayama (PR), and in preceding eyes closed baseline periods (PEC)

ECP, post-pranayama eyes closed period; ECC, potentials recorded in control sitting sessions conducted on the subjects before they learned the pranayama. n = number of replications on each subject; ns, number of subjects for the group mean, PR, pranayama; B, bhastrika pranayama; U, ujjayi pranayama. n.s. not significant (level of significance P > 0.050).

Subject	PR	Na wave (mean (S.D.)				Pa wave (mean (S.D.)		
		Pre initiation ECC (n = 6)	PEC (n =3)	PR (n =6)	ECP (n =3)	Pre initiation ECC (n = 6)	PEC (n =6)	PR (n =6)
PRJ	B	1.01 (0.33)	1.72(0.38)	6.83(2.11)	3.33 (1.78)	1.18 (0.78)	0.60 (0.35)	2.85 (2.27)
STP	B	0.24 (0.27)	0.71 (0.05)	3.78 (1.78)	0.45 (0.58)	0.38 (0.32)	0.83 (0.23)	2.33 (1.16)
SJR	B	0.70 (0.26)	1.09 (0.33)	1.84 (0.83)	0.63 (0.54)	0.53 (0.19)	0.84 (0.41)	0.53 (0.38)
NVR	B	0.80 (0.27)	0.40 (0.28)	1.90 (1.03)	0.58 (0.15)	0.36 (0.20)	0.44 (0.32)	0.53 (0.38)
(A) Sub-group mean (S.D.) ns = 4		0.68 (0.32)	0.98 (0.56)	3.58 (2.34)	1.24 (1.39)	0.61 (0.38)	0.61 (0.19)	1.56 (1.20)
RMC	U	0.92 (0.74)	2.89 (2.05)	3.53 (1.33)	2.24 (1.29)	0.77 (0.40)	2.13 (1.40)	2.06 (0.63)
RNG	U	0.48 (0.18)	2.74 (0.22)	1.69 (0.46)	0.77 (0.34)	0.93 (0.54)	0.55 (0.55)	2.01 (2.39)
SWT	U	1.02 (0.92)	1.22 (0.22)	1.29 (0.47)	1.44 (1.04)	1.35 (0.78)	0.62 (0.38)	0.50 (0.47)
SK	U	1.95 (0.58)	2.70 (1.35)	2.95 (0.71)	2.33 (0.49)	1.22 (0.39)	0.14 (0.88)	1.73 (0.35)
SKT	U	0.87 (0.23)	1.09 (0.27)	2.05 (0.67)	1.68 (0.81)	0.83 (0.38)	1.75 (0.62)	3.02 (0.78)
VD	U	1.03 (0.39)	0.26 (0.24)	0.88 (0.76)	0.24 (0.01)	0.06 (0.45)	0.82 (0.90)	0.93 (0.89)
(B) Sub-group mean (S.D.) ns = 6		1.04 (0.48)	1.48 (1.07)	2.06 (1.00)	1.45 (0.82)	0.95 (0.28)	1.16 (0.64)	1.70 (0.89)
Group mean (S.D) ns = 10		0.90 (0.44)	1.28 (0.90)	2.67 (1.73)	1.36 (1.01)	0.81 (0.35)	0.97 (0.55)	1.64 (0.96)
Paired t-test significances				$P < 0.025^a$				
				$P < 0.025^b$	n.s			$n.s^b$

a Comparison of PR against ECC., b Comparison of PR or ECP against PEC

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No differences in wave changes between the two types of pranayamas

There were no significant differences in the peaking arnplitudes and latencies of the waves recorded during the two types of pranayarnas, viz., in the ujjayi and bhastrika groups (Student's t-test). Further, the trend of increase of Na wave amplitude, and a reduction in its latency was generally observed during both types of pranayama practices. Hence the result of the 10 subjects were averaged together.

No alterations of the Na waves during period of attention to respiration in untrained subjects.

AEP-MLRs of a group of ten subjects untrained either in pranayama or in concentration, recorded during attention focussed on their unregulated tidal breathing and sensing the accompanying air flow through the nose, revealed no statistically significant (paired t-test) difference in the Na and Pa waves compared to those of the pre-attention baseline periods of the test sessions, repeated thrice in each subject. The Na wave peaking latencies (ms mean $\pm$ S.D. for 10 subjects) for the pre, during and post periods respectively were: 16.58 ± 1.57, 16.80 ± 1.25, 16.56 ± 1.52. The Na-wave peaking amplitudes (μV mean $\pm$ S.D.) for the pre, during, and post periods, respectively were: 1.08 ± 1.08, 0.83 ± 0.73, 0.83 ± 0.56, The usual trend of amplitude change in the subjects was towards reduction during the period of attention, contrary to the trend of increase occurring during pranayama.

TABLE II

Mean and S.D. of peaking latencies (ms) of wave of middle latency auditory-evoked potentials the remaining details are the same in Table 1.

Subject PR		Na wave (mean (S.D.))				Pa wave (mean (S.D.))		
		Pre initiation ECC (n = 6)	PEC (n =3)	PR (n =6)	ECP (n =3)	Pre initiation ECC (n = 6)	PEC (n =6)	PR (n =6)
PRJ	B	16.4 (0.49)	15.3 (0.78)	14.9 (0.36)	16.17(0.17)	25.3 (1.25)	23.3 (1.66)	22.8 (2.28)
STP	B	19.1 (3.26)	14.5 (1.18)	13.4 (0.92)	12.92 (0.58)	27.6 (3.38)	28.1 (1.59)	24.1 (4.35)
SJR	B	17.2 (0.83)	16.2 (0.48)	16.1 (0.87)	16.39 (0.92)	25.9 (3.44)	24.7 (3.34)	23.2 (1.51)
NVR	B	16.3 (2.92)	17.8 (0.32)	17.0 (1.12)	17.63 (0.52)	26.3 (3.35)	24.3 (0.80)	24.0 (3.05)
(A) Sub-group mean (S.D.) ns = 4		17.3 (1.29)	15.9 (1.41)	15.4 (1.55)	15.79(1.98)	26.27(0.97)	25.1 (2.08)	23.5 (0.62)
RMC	U	14.4 (0.97)	14.2 (0.82)	13.9 (0.32)	13.63(0.26)	24.4 (3.03)	20.5 (0.69)	22.3 (1.88)
RNG	U	17.6 (1.74)	19.5 (2.43)	16.6 (2.48)	16.92(0.31)	29.5 (3.40)	31.9 (1.91)	23.6 (5.04)
SWT	U	19.4 (1.72)	16.5 (1.19)	16.8 (1.20)	17.78(1.72)	30.4 (1.39)	26.9 (1.18)	27.7 (1.30)
SK	U	14.9 (0.39)	14.5 (1.28)	14.9 (0.88)	15.03 (0.37)	29.7 (1.56)	26.3 (3.35)	28.7 (1.96)
SKT	U	15.8 (0.90)	15.6 (0.82)	14.7 (0.94)	15.41 (1.03)	25.1 (0.62)	25.9 (1.53)	21.4 (1.01)
VD	U	17.6 (1.29)	17.2 (0.04)	15.5 (0.42)	16.14 (1.29)	27.5 (2.45)	28.2 (1.44)	24.9 (1.16)
(B) Sub-group mean (S.D.) ns = 6		16.6 (1.90)	16.3 (1.96)	15.4 (1.13)	15.77 (1.48)	27.76 (2.53)	26.6 (3.70)	23.5 (0.63)
Group mean (S.D) ns = 10		16.9 (1.63)	16.1 (1.69)	15.4 (1.23)	15.78 (1.59)	27.17 (2.11)	26.0 (3.11)	24.3 (2.31)
Paired t-test significances				$P < 0.025^a$	n.s[b]			n.s
				$P < 0.025^b$	n.s[b]			

DISCUSSION

The present results revealed that practice of ujjayi on bhastrika type of pranayama resulted in a significant increase in peaking amplitudes of Na wave (by 108% over PEC value), and a significant

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decrease (9% of ECC value) in its latency. No such alterations of Na wave were produced in untrained on the involuntarily on-going tidal breathing.

There were no alterations in the peaking amplitudes or latencies of the Pa wave. However, since it is well-known that the peaking of MLRs varies considerably (the later the wave type, the more of its variation, in general), it can not be ruled out that the Pa wave alterations may also attain statistical significance when a much larger number of subjects is examined.

The results support the view that the conscious pranayamic practice could lead to a generalized modulation of processing of signals, i.e., even in neural systems not involved in breathing regulation, and also that such a modulation could operate at the primary thalamo-cortical state. It has been postulated that the Na wave may be due to activity at the mesencephalic or diencephalic level and Pa wave to auditory cortex (Deiber et al., 1988). Also, experiencing pranayama exercise over the period of about 21 months did not seem to change the processing of signals at other times (non-pranayama periods) in the subjects, since there was no significant difference in the baseline values (PEC) of the Na wave, obtained before and after about the 21 months of pranayama practice. Hence, no permanent functional changes seem to have occurred in the auditory pathway at the level of generators of the Na wave, but the change occurred only during the periods of pranayama practice. Enhancement of Na wave under ordinary circumstances is interpretted to indicate a facilitation occurring in the processes of sensory signal transmission.

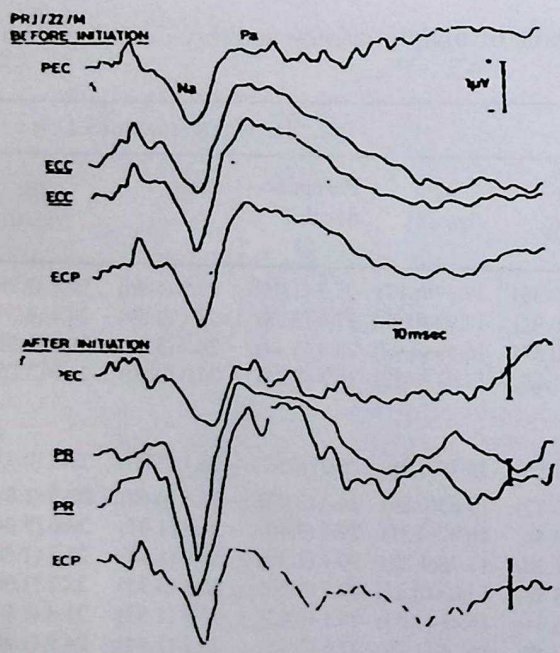

Fig. 2. Typical examples of AEP - MLRs recorded in a subject in a test session conducted before he was initialed into yogic practice, and again after having been initiated into yogic practiced for 23 months. In each test session, AEP-MLRs were recorded four times, i.e., before (PEC), after (ECP) and during the pranayamic practice period (PR). In the sessions conduted before initiatiation into yogic training also. AEP-MLRs were recorded in the same sequence of time period, the ECC corresponding to that of PR

Since pranayama is entirely a voluntarily-controlled exercise, and since the comparison has been made between the AEP-MLRs of unattended involuntary (tidal) breathing period and of the consciously generated pranayamic breathing in the same subjects, the difference in the waves has been considered to be due to the conscious mental exercise and attention underlying the controlled pranayamic breathing, which may be exerted through corticofugal influences. Also, during the period of normal type of attention held on on-going breathing by an untrained group of subjects, no indication of such a change in the auditory signal processing (Na wave) was observed. Hence, the changes in the Na wave could possibly be related to the process of acquisition of specialised skills through training in pranayama to be able to hold the attention and generate

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TABLE III

Statistical analysts of peakings of Na and Pa waves of MLRs

These were recorded during the condition of eyes closed control sitting periods with random thoughts (ECC) in test sessions conducted before the subjects were initiated and trained in pranayarna, and recorded again after practising pranayama for about 21 months, in test sessions containing pre-pranayama baseline periods of eyes closed state with random thoughts (PEC), and during periods of the pranayama (Ujjayi or Bbastrika) exercise with attention kept on the voluntarily regulated breathing and experiencing in eyes closed state the flow of breath (PR). Comparison is also made (in ANOVA-IV) with data of MLRs of an additional group of subjects uninitiated in pranayama, recorded in test periods of sitting in eyes closed state with random thoughts (PEC'), and during attention concentrated on the on-going tidal involuntary respiration and flow of breath through the nose in eyes closed state (ECC-concn.). For the ANOVA-1 and ll: *df* for F is 1,16; and P(I). n.s., not significant (P > 0.10). Other abbreviations are as in Table 1.

	Na wave peaking F and P values		Pa wave peaking F and P values	
	Amplitude	Latency	Amplitude	Latency
ANOVA 1				
a) Factor 1				
Sessions of ujjayi X	1.13	0.17	0.61	1.80
Bhastrika	n.s.	n.s.	n.s.	n.s.
b) Factor 2				
Conditions of				
ECC × PR	10.91	5.41	7.51	8.44
	< 0.005	< 0.05	< 0.025	- 0.01
c) a × b	2.95	0.29	2.25	0.01
interaction	n.s.	n.s.	n.s.	n.s.
ANOVA II				
a)Factor - 1				
Session of Ujjayi X	0.70	0.06	0.73	0.15
Bhastrika	n.s.	n.s.	n.s.	n.s.
b) Factor - 2				
Conditions of				
Pre - pranayama (PEC)	5.39	1.16	3.43	0.25
PR	< 0.05	n.s	< 0.09	n.s.
c) a × b	2.73	0.03	0.02	0.01
interaction	n.s.	n.s.	n.s.	n.s.
ANOVA III				
Repeated measures (conditions):			Tukey test (q (df, k)):	
ECC, PEC, PR	6.42		PEC vs. ECC = 1.035 (27,3) n.s.	
F df 2,27	approx. 0.005		PEC vs. PR = 3.787 (27,3) < 0.05	
			PEC vs. PR = 4.822 (27,3) < 0.01	
ANOVA IV				
Repeated measures (conditions)in two groups				
ECC', ECC - concn.,	4.88		PEC' vs. PEC = 0.53 (36,4) n.s.	
PEC, PR	< 0.01		PEC' vs. ECC-concn. = 0.67(36,4) n.s.	
F df 3,36			PEC vs. PR = 3.74 (36,4) < 0.06	
			ECC - concn. vs. PR = 4.94 (36,4) < 0.01	
Paired t-test	Ujjayi (U)	Bhastrika (B)	All (U and B)	
For Na amplitude				
PEC vs. PR	t(5) - 4.287	t(3) - 2.178	t(9) - 2.594	
	P(1) - 0.005	P(1) - 0.07	P(1) - 0.025	

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consciously the sensorimotor signals that produce the specific breathing rhythm and associated thoughts of sensation proficiently without letting in distractions or breaks. It should be recalled here that the original goal of yoga is not merely an attention-holding process, but is to ultimately acquire ability to control 'mindstuff from taking various forms' (Vivekananda, 1973). It has been also stated that through pranayama "we begin by controlling the breath, as the easiest way of getting control of the prana". "Thence arises supreme control of the organs" (Vivekananda, 1973).

It should also be mentioned here that in a separate study (unpublished) we have noted that the Na-wave changes were absent during pranayama in subjects of long-standing practice (more than 60 months experience of pranayama). The absence of the Na-wave change may be due to their practising pranayama for so long, by which time the practice would have become so automatic, like a reflexive automation, without needing much of a close attention and mental activity. In one subject (SKT), of the present group as well, a follow-up repeat study done after 30 months of pranayamic experience revealed that the Na-wave changes were no longer occurring during the pranayama session. This is consistent with what has been reported (Seitz et al., 1990) in voluntary motor learning, that alterations in activity (as seen through blood flow changes) or certain areas of the cerebral cortex 'vanished' after accomplishing the learning to perform a task automatically. When the discrete 'forms' of thoughts of sensation of the pranayamic exercise give place in automatic performance to a relatively uniform state of mind with some stilling of thoughts perhaps through other neural mechanisms, the general control over the primary thalamo cortical processes of information transmission may no longer be required. At the present time, little is known about neural structures and processes that generate transcendental and abstract states of conscious experiencing, in contrast to some knowledge available on the ordinary perceptions of self-conscious states. The types of association cortical neural mechanisms, in particular of the prefrontal system with its limbic interactions (Desiraju, 1979; 1981) that are usually supposed to play roles in determining the nature of contents and states of human mind have yet to be identified. Moreover, advancement in understanding the fundamental source of consciousness and its relation to brain will ultimately determine the extent to which the above can be understood (Desiraju, 1984). The Na-wave changes observed in auditory pathway during attention and conscious regulation of respiratory cycles in pranayama may reflect some generalized process of a dynamic change induced in neural activity at the mesencephalic or diencephalic level.

Oxygen consumption values (Telles and Desiraju, 1991) determined during the period of practice of ujjayi of the type comparable to the variety used in the present study indicated a reduction in metabolism by 19%, and no signs of hypo- or hyperventilation effects. Further, transient changes in systemic circulation do not effect cerebral metabolism due to auto-regulation of blood flow in brain. Hence, the increase in Na-wave amplitude (while the Pa wave remains unchanged) as observed in the present study can not be supposed to be due to any changes in levels of cerebral 0_2 or $C0_2$ as they are most unlikely to be caused.

ACKNOWLEDGEMENT

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LETTER TO THE EDITOR

HEART RATE ALTERATIONS IN DIFFERENT TYPES OF PRANAYAMAS

Sir,

(Received on April 7, 1992)

Pranayama is a state of voluntarily regulated breathing while the mind is directed to the feeling of the flow of breath or prana (1). A typical cycle of the slow type pranayamic breathing involves the phases of inhalation, exhalation, and timed breath-holding (kumbhak) either at end-inspiration stage or at end- expiration, or at both stages. There are different kinds of pranayamas varying according to the durations of the phases in the breathing cycle, and in other details like the nostrils used, and bandhas employed.

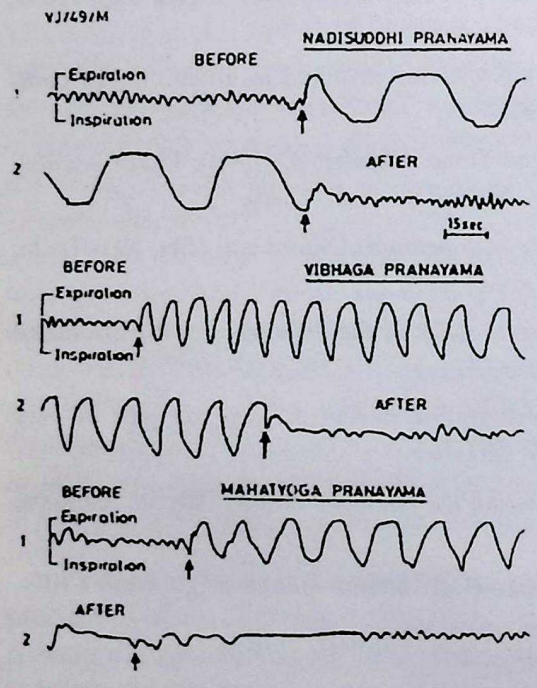

Fig1. Respirogram record taken before, during (1) and after (2) : Nadisuddhi, Vibhaga and Mahatyoga Pranayamas.

This report presents the differences in heart rate changes in 4 different kinds of pranayama, practised by a subject who had several years of experience.

At the time of the study, VJ was a 49 year old healthy male, with about 5 years of experience in practising different types of pranayamas (Fig. 1). The EKG of standard limb lead II, and respirogram via a mercury strain gauge wrapped around the chest, were recorded on a Beckman dynograph. The subject practised 4 types of pranayamas in the same session separated by 5 minute periods of relaxation in sukhasan in between the 4 pranayamas. The 4 pranayamas differed in the ratios of the durations of respiratory phases in a pranayama breathing cycle, i.e. inspiration (1); Kumbhak at end-inspiration (K-I) : expiration (E) kumbhak at end-expiration. These ratios were as follows: (1) in Savitri pranayama (SP) I:K - I:E:K-E = 2:1:2:1; (2) in Nadisuddhi pranayama (NP) I:K - I:K: K- E = 1:1:1:1; (3) in Mahatyoga pranayama (MP) (3 phases) I:E:K-E = 1: 1:0.25, and (4) in Vibhaga pranayama (VP) I:E:K-E = 1:1:0.20.

The results revealed an overall increase of heart rate during two pranayamas (VP and MP) of the 4 pranayamas, compared to the respective prepranayamic baseline values of the sukhasan sitting state (Table 1). These 2 pranayamas (VP, MP) have no end-inspiratory kumbhak (K-I), and have only a short end-expiratory Kumbhak (K-E.). In the other two pranayama (SP and NP). i.e., the two varieties which had end - inspiratory (K-I) and end-expiratory (K-E) kumbhak phases, the mean of the overall heart rate was not significantly altered.

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A previous report (2) on heart rate changes in Savitri Pranayama showed that the heart rate was higher during inspiration than during expiration, in eupnoea, during deep breathing, and during Savitri pranayama

Table 1: Heart rate and respiratory rate changes in 4 different pranayamas.

Parameters	I Normal breathing Eyes closed, in Sukhasan	II Vibhaga Pranayama	III Mahatyoga Pranayama	IV Savitri Pranayama	V Nadisuddhi Pranayama
Heart rate per minute	76.50 ± 3.89	92.16 ± 1.75*	87.37 ± 2.86*	78.83 ± 2.11	77.64 ± 1.97
Respiratory rate per Minute £	17.25 ± 1.19	4.33 ± 0.28	3.62 ± 0.14	2.48 ± 0.18	1.42 ± 0.12
No. of values averaged	4	3	4	6	7

** P<0.05 against value of eyes closed (Sukhasan), Student's t-test (2 tailed). £: No statistical comparisons were made with 'eyes closed (sukhasan)' value as respiration was voluntarily slowed down. I: inspiration phase. K - I: kumbhak phase at end-inspiration. E: expiration K - E : kumbhak phase at end - expiration.*

However, the increased rate during the inspiratory phase of Savitri Pranayama was significantly more than for eupnoea or deep breathing. In present report in two pranayamas (MP, VP) the heart rate was more during inspiration (mean ± S.D. 90.5 ± 2.4 beats/min) and less during expiration (mean ± S.D. 87.0 ± 3.0 beats /min). Both values were significantly higher than corresponding (i.e., inspiratory or expiratory) values of quiet breathing in the preceding baseline period. In the 2 remaining pranayamas (SP, NP) the heart rate was higher during expiration (mean ± SD 78.0 ± 0.5 beats / min) than during inspiration (mean 74.1 ± 2.0 beats/min). However, the highest value was during the end-inspiratory kumbhak (mean ± S.D. 79.1 ± 2.2 beats/min) and lowest during end-expiratory kumbhak (Mean ± S.D. 71.9 ± 0.3 beats/ min). The inspiratory and expiratory heart rate values did not differ significantly from the corresponding values of the preceding baseline period.

This is an example showing that different types of heart rate alterations may occur in different types of pranayamas, and that the short kumbhak type of pranayamas may not cause a change in the mean heart rate.

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BREATHING THROUGH A PARTICULAR NOSTRIL CAN ALTER METABOLISM AND AUTONOMIC ACTIVITIES

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(Received on July 15, 1993)

Abstract: There is increasing interest in the fact that breathing exclusively through one nostril may alter the autonomic functions. The present study aimed at checking whether such changes actually do occur, and whether breathing is consciously regulated. 48 male subjects, with ages ranging from 25 to 48 years were randomly assigned to different groups. Each group was asked to practice one out of three *pranayamas (viz.* right nostril breathing, left nostril breathing or alternate nostril breathing). These practices were carried out as 27 respiratory cycles, repeated 4 times a day for one month. Parameters were assessed at the beginning and end of the month, but not during the practice. The 'right nostril pranayama' group showed a significant increase, of 37% in baseline oxygen consumption. The 'alternate nostril pranayam' a group showed an 18% increase, and the left nostril *pranayama* group also showed an increase, of 24%. This increase in metabolism could be due to increased sympathetic discharge to the adrenal medulla. The 'left nostril *pranayama'* group showed an increase in volar galvanic skin resistance, interpreted as a reduction in sympathetic nervous system activity supplying the sweat glands. These results suggest that breathing selectively through either nostril could have a marked activating effect or a relaxing effect on the sympathetic nervous system. The therapeutic implications of being able to alter metabolism by changing the breathing pattern have been mentioned.

Key words : *yogic breathing; unilateral nostril breathing; oxygen comsumption; automic function.*

INTRODUCTION

The nasal cycle is an ultradian rhythm during which the patency and functional efficiency of the right and left nares changes alternately with an average periodicity of about 2 to 3 hours when awake (1,2). The link between the sympathetic and parasympathetic divisions of the autonomic nervous system and the nasal cycle, has been worked out by experiments on humans (2,3) and in non-human species, as well (4). Whether breathing through a particular nostril could selectively activate either division of the autonomic nervous system, has been tested by studying the effects of forced unilateral nostril breathing on autonomic activities. Werntz and colleagues (5) correlated right nostril dominance with the 'activity phase' of the basic rest activity cycle. This has been validated by the work of Backon (6) which showed that forced right nostril breathing significantly increases blood glucose levels, whereas left nostril breathing lowers it.

The ancient Indian science of *Yoga* makes use of voluntary regulation of the breathing to make respiration rhythmic, and to calm the mind. This practice is called *Pranayama.* Some varieties of *Pranayama* require the practitioner to inhale and exhale through one nostril selectively. These *Yogic* practices provide an opportunity to study the effects of selective nostril breathing carried on effortlessly for prolonged periods. When each respiratory cycle is completed through the right nostril excusively, the practice is called *Surya Anuloma Viloma Pranayama,* which means 'heat

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generating breathing practice', and when completed through the left nostril alone, the practice is called *Chandra Anuloma Viloma pranayama,* which means a 'heat dissipating or cooling breathing practice'. In *Nadisuddhi Pranayama* (which means 'purification of subtle energy paths'), inhalation and exhalation are through alternate nostrils for successive respiratory cycles. These names were given based on the subjective experiences of the ancient sages.

The present Study has been carried out to assess whether practising any one of the three *Pranayamas* described above, for a month, would cause changes in baseline metabolic and autonomic activities.

METHODS

Subjects: The subjects had come to the Vivekananda Kendra *Yoga* Research Foundation, Bangalore, India, to receive one month's training in *Yoga.* The study was explained to the subjects, and their signed informed consent was taken according to the ethical principles of the Indian Council of Medical Research, New Delhi, India. There were two groups with 24 subjects in each (i.e., a total of 48 subjects). All of them were males, with ages ranging from 25 to 48 years (Mean 34.07, SD 5.9 years).

The first group was randomly sub-divided into two groups. Both groups were given the customary training in *Yoga* (detailed below). In addition to this training, based on a random allocation, one group was asked to practice 27 respiratory cycles through the right nostril, repeated 4 times during the day *(the Surya Anuloma Viloma Pranayama* group or 'S' group). The other group practised 27 respiratory cycles through alternate nostrils (the *Nadisuddhi Pranayama* group or 'N' group), repeated 4 times during the day. These practices were continued throughout the one month of training. The other group was similarly randomly divided as two groups. For these groups also, in addition to the customary training in *Yoga,* one group was asked to practice 27 respiratory cycles through the left nostril, 4 timers a day, (the *Chandra Anuloma Viloma or 'C'* group) whereas the other group completed 27 respiratory cycles through alternate nostrils (the *Nadisuddhi Pranayama* or 'N' group), which had the same pranayama practice as the 'N' group of the first batch). This design was chosen as the 'N' group was considered as a control for both the 'S' and the 'C groups.

Parameters: In both groups the following parameters were assessed, at the beginning and at the end of the one month period viz. Galvanic skin resistance (GSR) and stethographic record of respiration using a 4 - channel portable polygraph (Lafayette, USA). The GSR was measured using specially designed metal plates placed in contact with volar surfaces of the ring and the index fingers. Oxygen consumption using the closed - circuit Benedict - Roth apparatus (INCO, India) was measured at 4.00 a.m. before the daily schedule began. Since the training camps were residential it was possible to keep several factors constant, such as the diet and meal times.

Design of the study and statistical assessment: Following their arrival at the *Yoga* training centre, subjects were given a day to get used to the routine, and then the initial assessments were made. After a month of *yogic* training, the assessments were repeated. The initial and final values were compared for significant differences using the non-parametric paired signed rank test (of Wilcoxan). No assessments were made during the *pranayama* practice.

Training in YOGA : All four groups of subjects received the same regular *Yoga* training. This consisted of different *asanas* (physical postures), *Pranayama* (voluntary regulation of breathing), meditation, devotional sessions, and lectures on the theory and philosophy of *Yoga.* The pranayama

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practice of the regular schedule consisted of nine rounds of *Nadisuddhi Pranayama,* as well as other varieties involving slow, deep respiration, but without manipulating the nostrils, as is required for *Surya Anuloma Viloma and Chandra Anuloma viloma.*

In addition, according to their random allocation to different groups, subjects were asked to practice one of the following *pranayama* (voluntary regulation of breathing) : *(1) Surya Anuloma Viloma Pranayama* (both inhalation and exhalation through the right nostril), *(2) Chandra Anuloma Viloma Pranayama (both* inhalation and exhalation through the left nostril), and *(3) Nadisuddhi Pranayama* (inhalation and exhalation through alternate nostrils). Subjects were asked to practice whichever *Pranayama* was specifically assigned to them, as 27 respiratory cycles, repeated 4 times everyday, throughout the one month of training.

RESULTS

Effects of *Surya Anuloma Viloma Pranayama (right nostril breathing or 'S' group) and Nadisuddhi Pranayama (alternate nostril breathing or 'N' group): The* 'S' group showed a statistically significant ($P<0.05$, Wilcoxan's paired signed rank test) increase of 37% in baseline levels of oxygen consumption. However, the 'N' group did not show such a significant change (i.e. a 19%, non-significant increase was observed).

Both groups showed a comparable and significant reduction in body weight ranging from 4.2 to 5.1%, ($P<0.001$, Wilcoxan's paired signed rank test). Also, both groups showed a significant increase in heart rate at the end of a month ($P<0.001$, Wilcoxan's paired-signed ranks test). The volar galvanic skin resistance (GSR) and respiratory rate did not alter in either group (Table 1).

Effects of *Chandra Anuloma Viloma Pranayama (Left nostril breathing or 'C' group) and Nadisuddhi Pranayama (alternate nostril breathing or 'N' group) :* Both 'C' and 'N' groups showed an increase in baseline oxygen consumption (by 24% and 17%, respectively), though this was not statistically significant for either group ($P>0.01$, Wilcoxan's paired signed rank test).

Table I. This table gives a summary of the effects of 'S' Group and 'N" Group pranayamas.

Parameter	'S' Group Right Nostril Pranayama (12 Subjects)		'N' Group Alternate Nostril Pranayama (12 Subjects)	
	Initial value	Final value	Initial value	Final value
1. Oxygen Consumption (ml / min STPD)	443.8 ± 15.3	608.1 ± 17.6	464.3 ± 16.0	553.3 ± 14.3
2. Body Weight (Kg) (ml / min STPD)	54.4 ± 2.4	52.1** ± 2.1	58.7 ± 3.2	55.7** ± 3.0
3. Volar Galvanic Skin resistance (Kilo Ohms)	104.7 ± 18.7	103.0 ± 19.8	113.7 ± 20.0	110.0 ± 14.8
4. Respiratory rate (breath per minute)	14.9 ± 1.3	15.1 ± 1.2	15.4 ± 1.6	15.4 ± 1.8
5. Heart rate (beats per minute)	62.2 ± 4.4	68.2** ± 2.8	63.0 ± 2.8	68.35** ± 1.9

*Values are mean ± S.E.M. (Standard error of mean). Statistical significance of final values has been indicated with asterisks, as follows: * = $P < 0.05$. ** = $P < 0.001$. Wilcoxan's non-parametric paired signed rank test.*

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Table II: This table gives a summary of the effects of 'C' Group and 'N' Group pranayama

Parameter	'C' Group Right Nostril Pranayama (12 subjects)		'N' Group Alternate Nostril Pranayama (12 subjects)	
	Initial value	Final value	Initial value	Final value
1. Oxygen Consumption	438.2 ± 13.9	538.8 ± 15.6	453.8 ± 16.2	529.0 ± 18.1
2. Body Weight (Kg)	60.30 ± 1.60	58.00* ± 1.70*	56.7 ± 2.8	55.2 ± 2.6
3. Volar galvanic Skin Resistance (Kilohms)	90.8 ± 18.5	222.5* ± 47.3	90.5 ±10.6	93.7 ± 14.5
4. Respiratory rate (Breaths per Minute)	17.1 ± 1.1	15.8 ± 1.2	14.8 ± 0.9	13.8 ± 1.2
5. Heart rate (Beats per minute)	64.0 ± 2.1	67.3 ± 3.2	65.0** ± 0.9	69.1** ± 1.6

*Values are Mean ± S.E.M. (Standard error of mean). Statistical significance of final values comared with initial values has been indicated with asterisks as follows: * = P < 0.05, ** = P < 0.001, Wilcoxan's non - parametric paired signed rank test*

The 'C' group showed a statistically significant increase, in volar galvanic skin resistance (CSR), (P<0.05, Wilcoxan's paired signed rank test). In contrast the 'N' group did not show such a change. In contrast, the 'N' group showed a significant increase in heart rate (P<0.001) while the 'C' group did not change. Both groups showed a comparable (ranging from 3.8 to 2.6%) and significant (P<0.05, Wilcoxan's paired signed rank test) reduction in body weight. Neither group showed change in respiratory rate (Table II).

DISCUSSION

The present study has shown that breathing exclusively through the right nostril several times a day, for a month can significantly increase the baseline oxygen consumption by 37%, whereas repeated breathing through the left nostril alone, or through alternate nostrils produces a smaller increase, which was not statistically significant. Neither respiratory rate nor galvanic skin resistance changed with right nostril or alternate nostril breathing. In contrast, breathing through the left nostril exclusively repeated four times a day for a month produced a significant increase in the baseline level of volar galvanic skin resistance (GSR), suggestive of reduced sympathetic activity to the palmar sweat glands. Alternate nostril breathing repeated regularly for one month did not have this effect.

All 3 types of *Pranayamic* practice caused a reduction in body weight (Mean 2.27, SD 0.61 kg). Since we had noted that previous groups of Yoga course participants had a similar percentage reduction in body weight, we attributed this reduction to their change in diet (a vegetarian diet devoid of saturated fat), as well as increased physical activity. We did not correlate their reduction in weight with any one of the three types of Pranayama practices, specially.

We can speculate that right nostril breathing increases metabolism perhaps by increasing the output of adrenaline from the adrenal medulla, (reflected in the significant increases in baseline oxygen consumption and heart rate) while sympathetic output to the sweat glands does not change

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(stable GSR). In contrast left nostril breathing produced a marked decrease in sympathetic activity to the sweat glands whereas other subdivisions did not change as much (relatively smaller changes subdivisions did not change as much (relatively smaller changes in baseline oxygen consumption and heart rate).

An interesting point is that in the same group (i.e. left nostril group) subjects, there was an increase in oxygen consumption (suggestive of increased sympathetic discharge to the adrenal medulla), and an increase in galvanic skin resistance (suggestive of reduced sympathetic tone to the palmar sweat glands and cutaneous blood vessels). This apparent disparity can be explained by the fact that each target of sympathetic innervation receives its own outflow, and the factors influencing it may differ from one part of the body to another. Hence the traditional concept of diffuse sympathetic tone cannot be maintained (7). It is also known that the sympathetic outflow to palmar sweat glands and cutaneous blood vessels change with the mental state (7). Since these nerves influence the GSR, we may speculate that reduced mental stress or arousal caused the increase in GSR, while some other (unknown) factor altered the sympathetic nervous system outflow to the adrenal medulla, to produce an increase in oxygen consumption.

The exact mechanism by which nostril breathing influences the function of the autonomic nervous system is not known, though it has been speculated (2) that this is through a neural reflex mechanism in the superior nasal meatus.

Further work is necessary to understand the mechanism, as well as to record changes during the actual practice. However, at this stage one may suppose that the effect of these pranayama practices can be used for therapeutic advantage. For example, several rounds of *Surya Anuloma Viloma Pranayama,* could be used to increase metabolism, in over weight persons, while the effects of the other two *prayanamas* would not be as marked.

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PHYSIOLOGICAL MEASURES OF RIGHT NOSTRIL BREATHING

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Abstract : This study was conducted to assess the physiological effects of a yoga breathing practice that involves breathing exclusively through the right nostril. This practice is called surya anuloma viloma pranayama (SAV). Twelve volunteers (average age 27.2 years ± 3.3 years, four males) were assessed before and after test sessions conducted on two consecutive days. On one day the test session involved practicing SAV pranayama for 45 minutes (SAV session). During the test period of the other day, subjects were asked to breathe normally for 45 minutes (NB session). For half the patients (randomly chosen) the SAV session was on the first day and the NB session on the next day. For the remaining six patients, the order of the two sessions was reversed. After the SAV session (but not after the NB) there was a significant ($P < .05$, paired t test) increase in oxygen consumption (17%) and in systolic blood pressure (mean increase 9.4mm Hg) and a significant decrease in digit pulse volume (45.7%). The latter two changes are interpreted to be the result of increased cutaneous vasoconstriction. After both SAV and NB sessions, there was a significant decrease in skin resistance (two factor ANOVA, Tukey test). These findings show that SAV has a sympathetic stimulating effect. This technique and other variations of unilateral forced nostril breathing deserve further study regarding therapeutic merits in a wide range of disorders.

INTRODUCTION

The nasal cycle is an ultradian rhythm with a periodicity of about two to eight hours, during which the right and left nares are alternately patent (Keuning, 1968). Forced right nostril breathing occluding the left nostril was found to increase blood glucose levels (Backon, 1988) and heart rate (Shannahoff-Khalsa & Kennedy, 1993). In a detailed review (Shannahoff-Khalsa, 1991) a number of other physiological and psychological effects of right nostril breathing were suggested, such as generalized sympathetic tonus, increased temperature and metabolic rate, and improved verbal performance. Left nostril breathing had reverse effects. Based on this, the right nostril dominant stage was correlated with the activity phase of the basic rest-activity cycle (BRAC) and with an increase in the sympathetic tone (Werntz, Bickford, Bloom & Shannahoff-Khalsa, 1983). The left nostril dominant stage was correlated with the resting phase of the BRAC and with parasympathetic dominance.

Some varieties of yoga breathing (pranayama) involve inhalation and exhalation through one nostril exclusively. These yoga practices provide an opportunity to study the effects of selective nostril breathing for prolonged periods. Some of the physiological effects of a month of right nostril breathing pranayama (surya anuloma viloma or SAV), practised for ten minutes four times in a day, were found to be significantly different from the effects of a left nostril breathing pranayama (chandra anuloma viloma or CAV) and an alternate nostril breathing pranayama (nadisuddhi or NDS), when all three techniques were practiced for the same frequency and duration (Telles, Nagarathna Nagendra, 1994). SAV caused a significant increase in oxygen consumption (37%), whereas both left and alternate nostril breathing caused a nonsignificant increase in oxygen consumption (24% and 19%, respectively). With all three practices there was a significant decrease in body weight. This reduction was comparable for SAV and CAV (2.3 kg) and less for NDS (1.5 kg). With CAV alone there was a significant decrease in volar skin

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resistance, interpreted as a reduction in sympathetic tone. While both SAV and CAV were accompanied by a reduction in body weight, SAV alone significantly increased the oxygen consumption. The increase in OC (albeit not significant) following CAV could mean that CAV practice is not actually "cooling" as described by the ancient yoga texts, but more accurately *less* stimulating than SAV. Of course, the increase in skin resistance following CAV practice shows that this practice *does* reduce sympathetic activity at least in some divisions of innervation.

The comparable reduction in body weight with both SAV and CAV suggests a possible therapeutic application in obesity for both these practices. However, the maximum increase in oxygen consumption following SAV makes this practice preferable to CAV, particularly in view of the fact that the resting metabolic rate (RMR) in kcal/kg/hour is lower in the obese and is negatively correlated with the body mass index (BMI) (Dudani, Bijlani, Gupta, Manoch & Nayar, 1986).

Obesity is well known to be associated with a variety of diseases, particularly hypertension and coronary heart disease (Mayer, 1980). Hence, the present study was designed to assess the immediate effects of 45 minutes of SAV pranayama on blood pressure (BP), digit pulse volume, heart rate, breath rate, skin resistance, and oxygen consumption. This information was considered necessary to understand any possible therapeutic merits (and limitations) of this breathing technique.

MATERIAL AND METHODS

Subjects

Twelve volunteers, (four males), age range 21 to 33 years (age mean (SD), 27.2 (3.3) years) participated in the study. None had a history of major illnesses, and on a routine medical examination they were all found to be of normal health. All twelve subjects resided for approximately three months prior to testing at the place where the tests were held. This allowed their diet and schedule (e.g., meal times and time of waking up or sleeping) to be kept constant on the day before testing and on the two days of assessment. The subjects had all been practicing different yoga techniques (asanas and pranayamas, excluding SAV) for approximately ninety minutes every day, during the three months prior to the study. The subjects *did not* practice the yoga techniques during the days of the study in order to reduce the chance of the short-term effects of these practices modifying the effects of the pranayama practice (i.e., SAV) that was studied.

Design of the study

Assessments were made on two separate days as soon as the subjects woke up in the morning, between 4:15 AM and 5:30 AM. Assessments were taken, followed by the test period (45 minutes), at the end of which assessments were repeated. On day one the test period involved practicing surya anuloma viloma pranayama (SAV) for 45 minutes. This involves breathing exclusively through the right nostril. On day 2, during the 45-minute test period, subjects were asked to breathe normally. This was called the NB session. Half the subjects (selected on a random basis) were given SAV sessions first, followed by NB sessions on the next day. The six remaining subjects had NB sessions on day one and SAV sessions the next day.

Assessments

The sequence of assessment was the same for the recordings made before and after the test periods of both SAV and NB. The sequence was as follows: Subjects were asked to rest for 5

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minutes, seated at ease. Oxygen consumption (OC) was recorded for 5 minutes using the closed circuit Benedict-Roth apparatus. Recordings were made almost immediately after waking up in the morning. This was followed by a 10-minute recording of polygraph data viz. heart rate through EKG, skin resistance, respiration, and digit pulse volume as detailed below. The blood pressure (BP) was recorded once at the end of the 10-minute recording. This sequence was repeated at the end of the test period.

Oxygen consumption (OC) was recorded for 5 minutes using the closed circuit Benedict-Roth apparatus. Recordings were made almost immediately after waking up in the morning. Polygraphic recordings were made using a 10 channel polygraph (Model 10, Polyrite, Recorders and Medicare, Chandigarh, India). The EKG was recorded using standard limb lead 1 configuration. The skin resistance (SR) was recorded using specially contoured metal electrodes smeared with electrode jelly (Medicon, Madras, India) and placed in contact with the volar surfaces of the distal phalanges of the index and middle fingers of the left hand. A fixed current of 1OuA was passed between the electrodes. Respiration was recorded using a volumetric pressure transducer fixed around the trunk about 8 cm below the lower costal margin as the subject sat erect. A photo-plethysmograph was placed on the volar surface of the distal phalanx of the left thumb to record the digit pulse volume (DPV).

The blood pressure was recorded with a standard mercury sphygmomanometer, auscultating over the right brachial artery. The diastolic pressure was noted as the reading at which the Korotkoff sounds appeared muffled. Recordings were made of the (subjective) feelings the subjects experienced at the end of both sessions. Subjects were shown how to monitor their nasal airflow using a method described earlier (Klein, Pilon, Prossner & Shannahoff- Khalsa, 1986), by breathing on a glass slide and noting which patch of mist was smaller and/or faded more quickly.

Data acquisition and analyses

The OC was calculated in ml/min and converted to ml/min Standard Temperature and Pressure Dry (STPD), according to the accepted procedure (Report of the International Union of Physiological Sciences Commission on Teaching Physiology, 1991). Heart rate (HR) in beats per minute (bpm) was obtained by continuously counting the QRS complexes in successive 60 second periods. The skin resistance (SR) trace was sampled every 30 seconds. The amplitude of the digit pulse volume (DPV) was sampled from the peak of pulse wave at 30-second intervals and converted to millivolts (mV) (Roy & Steptoe, 1991).

The data were analyzed using the 2-factor ANOVA, the multiple comparison Tukey test, and the paired t test. The ANOVA was used to determine whether there was a significant difference between SAV and NB sessions (Factor A), the readings before the test period compared to the readings obtained after it (Factor B), and interaction between Factors (A X B). The multiple comparison Tukey test was used to check the least significant difference between different pairs of means. As a second level analysis, the t test for paired data was used to compare the initial and final data of SAV and NB sessions separately.

Pranayama (SAV) and normal breathing (NB)

During both surya anulorna viloma pranayama (SAV) and normal breathing (NB), subjects sat either in padmasana (lotus posture) or sukhasana (sitting cross-legged at ease), with their eyes closed. Surya anuloma viloma pranayama (SAV) involves breathing exclusively through the right nostril, while the left nostril is kept occluded with gentle pressure from the ring and little

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finger of the right hand (Nagendra, Mohan & Shriram, 1988). During normal breathing (NB) there was no voluntary manipulation of the nostrils.

During the three months prior to the study, the subjects practiced the following yoga techniques:

1. ***Asanas***: ardha cakrasana/ lateral arc posture (left and right side), ardha cakrasana/ half-wheel posture, padahastasana/ forward-bend posture, ardha matsyendrasana/ half-twist posture, ustrasana/ camel posture, pascimotanasana/ posterior stretching, bhujangasana/ serpent posture,Salabhasana/ locust Posture, dhanurasana/ bow Posture, sarvangasana/ shoulder-stand, matsyasana / fish Posture, and Savasana/ corpse Posture.

2. ***Pranayamas***: sectional breathing, nadisuddhi (purification of subtle perception paths), ujjayi (hissing pranayama), and bhrahmari (bee sounding pranayama).

RESULTS

The group mean values ± SD for all the parameters have been given in Table 1.

Two Factor ANOVA

The two factor ANOVA revealed a significant difference between the "before" and "after" values of skin resistance-SR (viz Factor B = before test period versus after test period), [F = 8.54, F 0.02 (2) 1,44 = 7.24 hence P < 0.021, here (as well as below) the "F" value for DF 44 has been

Table 1. Autonomic Variables Before and After Surya anuloma pranayama (SAV) and Normal breathing (NB) values are groupes Mean ± SD, Number of subjects = 12.

	SAV		NB	
Parameters	Before	After	Before	After
Heart rate (bpm)	67.7 ± 10.0	66.0 ± 11.0	65.0 ± 8.1	64.5 ± 93.0
Respiration rate (cpm)	13.9 ± 5.4	13.5 ± 4.8	12.8 ± 4.4	12.1 ± 5.2
Skin Resistance (K ohms)	461.3 ± 312.0	183.0** ± 159.2@	444.0 ± 280.0	306.0** ± 205.7
Digital pulse Volume (mm)	7.0 ± 208	3.8* ± 1.8	6.6 ± 4.6	6.7 ± 5.0
Systolic BP (mm Hg)	100.6 ± 9.8	110.0* ± 9.6	104.5 ± 10.1	101.7 ± 10.9
Diastolic BP (mm Hg)	74.7 ± 11.5	72.5 ± 9.8	71.2 ± 7.3	69.8 ± 7.5
Oxygen consumption (ml/ min STPD)	257.4 ± 54.0	301.1* ± 51.1	251.6 ± 40.0	205.3 ± 59.2

**p < 0.05, paired t-test, "after" compared to "before"*
***p< 0.01, paired t-test, "after" compared to "before"* *@ p< 0.05, Tukey test,*

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derived by linear interpolation (Zar, 1984) from the values for DF = 40 and DF = 45, given in a standard table. The multiple comparison Tukey test revealed a significant difference between the mean SR value *after* SAV compared to the mean value *before* SAV ($q = 3.91$, where $q\ .05\ (2)\ 4, 40 = 3.79$, hence $P < 0.05$). Here 40 is the next value listed on the standard table where 44 is not listed.

For the systolic BP, interaction between Factor A (SAV versus NB) and Factor B (before versus after), i.e., A X B was significant [$F = 4.54$, $F\ 0.05\ (1), 1, 44 = 4.06$, hence $P < 0.0,5$]. However, there was no significant effect of either Factors A or B independently ($P > 0.2$, in both cases, DF as described above). There was no significant effect of either of the Factors (A or B) or of the interaction between them (A X B) for the remaining parameters ($P > 0.2$ in all cases, DF as described above). The multiple comparison Tukey test did not reveal a significant difference in the comparison of the group mean values for these parameters (for all parameters $q < 2.50$, DF as described above for SR, hence $P > 0.1$).

Paired t test

The paired t test revealed a significant decrease (45.7%) in digit pulse volume (DPV) following SAV ($P < 0.05$), with no significant change after NB. There was a significant ($P < 0.05$) increase of 17% in the oxygen consumption (OC) after SAV and in the systolic blood pressure after SAV sessions by an average of 9.4 mm HG ($P < 0.05$), but not after NB sessions. The skin resistance (SR) was significantly reduced after both SAV and NB sessions ($P < 0.001$, in both cases). The change was greater after SAV sessions (60%), compared to a 31% decrease after NB sessions. However, this difference was not statistically significant [$q = 1.72$, where $q\ 0.5\ (2)\ 4, 40 = 1.996$, hence $P > 0.5$].

There were no significant changes in the other parameters after either SAV or NB sessions, compared to before ($P > 0.1$) in all cases).

DISCUSSION

The present study has demonstrated a significant (paired t test) increase in OC (17%), systolic BP (9.4 mm of Hg on an average), and a significant decrease in digit pulse volume (45.7%), after SAV, with no change in these measurements after NB. After both SAV and NB there was a significant decrease (two Factor ANOVA, Tukey test) in SR.

The immediate effects of SAV on oxygen consumption shown in the present study are similar to the changes in baseline status reported after a month of SAV practice (Telles et al., 1994). This increase in oxygen consumption was considered especially interesting with a possible application in the obese who are known to have a lower Resting Metabolic Rate (RMR) in *Kcal/kg/hour* than the nonobese (the RMR is negatively correlated with the body mass index, or BMI) (Dudani et al., 1986). This effect is indeed in keeping with the name ('surya anuloma viloma pranayama'), which means "heat generating breathing practice" (Nagendra et al., 1988). In this context it may be mentioned that in the earlier study (Telles et al., 1994) the practice of CAV ("chandra anuloma viloma pranayama" or "heat dissipating" breathing practice) also increased the OC though the increase was not significant and was of a lesser magnitude than that caused by SAV (24% versus 37%). Hence the name ("heat dissipating") breathing practice may be mainly *relative* to SAV.

Apart from the effects on OC, the practice of SAV for a month caused an increase in heart rate, suggestive of increased cardiac sympathetic tone and/or reduced vagal tone (Telles et al.,

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1994). In the present study, immediately after SAV there was a significant reduction in skin resistance (SR) and in digit pulse volume (DPV), both indicative of an increase in sympathetic tone (to palmar sudomotor glands and cutaneous vasculature, respectively). These results support those of previous studies which have demonstrated the sympathetic stimulating effect of forced right nostril breathing (Backon, 1988; Shannahoff-Khalsa & Kennedy, 1993). The increase in systolic BP observed here was probably due to cutaneous vasoconstriction (as shown by the decrease in digit pulse volume). Both SAV and NB sessions caused a significant reduction in the SR. The reduction in SR after NB sessions could indicate an increase in the sympathetic activity in subjects sixty minutes after waking, as a "wearing off" of the increased SR known to occur during, sleep (Tart, 1967). All subjects-irrespective of which nostril was dominant at the start of the test session-showed these effects, suggestive of sympathetic stimulation.

It was interesting to note that at the end of the SAV test session, nine of twelve subjects reported feeling more relaxed, while at the end of the NB session eight subjects felt greater relaxation. Among these subjects there were six who reported feeling relaxed after both sessions. In the present study the subjects had practised yoga for three months prior to the study. The practice of yoga has been shown to reduce anxiety and increase quietitude (Hjelle, 1974). Hence, the earlier practice of yoga in the subjects of the present study may have added to the sympathetic stimulating effects of SAV, so that subjects felt more relaxed, though physically they showed signs of sympathetic stimulation. However, it is important to note that the subjects' prior experience of yoga could be expected to condition their autonomic nervous systems, so that their response to SAV may not be the same as that of naive subjects who have no prior experience of yoga.

The way in which breathing through either nostril can influence autonomic functions is not well understood. A study of the electrographic activity generated by nasal (as opposed to oral) breathing (Kristof, Servit & Manas, 1981), showed that this activating effect could also be produced by nasal insufflation without inflating the lung. This neural reflex was abolished after injecting local anesthesia into the nasal mucosa. The afferents arising from the mucosa are believed to be connected to both the hypothalamus (hence the autonomic nervous system) and the cerebral cortex; however, these pathways have not been anatomically defined.

In summary, the practice of SAV may be of benefit in obesity, but in view of the increase.in systolic BP and cutaneous vasoconstriction, it may be best to avoid this practice in obese patients who are also hypertensive.

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EFFECT OF TWO SELECTED YOGIC BREATHING TECHNIQUES ON HEART RATE VARIABILITY

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Abstract : The heart rate variability (HRV) is an indicator of the cardiac autonomic control. Two spectral components are usually recorded, viz. high frequency (0.15- 0.50 Hz), which is due to vagal efferent activity and a low frequency component (0.05- 0.15 Hz), due to sympathetic activity. The present study was conducted to study the HRV in two yoga practices which have been previously reported to have opposite effects, viz, sympathetic stimulation (kapalabhati, breathing at high frequency, i.e., 2.0 Hz) and reduced sympathetic activity (nadisuddhi, alternate nostril breathing). Twelve male volunteers (age range, 21 to 33 years) were assessed before and after each practice on separate days. The electrocardiogram (lead 1) was digitized on-line and off- line. analysis was done. The results showed a significant increase in low frequency (LF) power and LF/HF ratio while high frequency (HF) power was significantly lower following kapalabhati. There were no significant changes following nadisuddhi. The results suggest that kapalabhati modifies the autonomic status by increasing sympathetic activity with reduced vagal activity. The study also suggests that HRV is a more useful psychophysiological measure than heart rate alone.

Key words: *Heart rate variability; high frequency breathing; alternate nostril breathing; autonomic status.*

INTRODUCTION

Ancient yogic texts have described a rapid breathing cleansing practice (kapalabhati) as stimulating, and slow regulated breathing, particularly through alternate nostrils (nadisuddhi pranayama) as calming (1). These descriptions have been substantiated by scientific studies. Kapalabhati was found to cause "autonomic activation". This was observed as an immediate effect during three contiguous sessions of 5 min each, in terms of an increased heart rate and systolic blood pressure during kapalabhati (2). In contrast, nadisuddhi pranayama practised for four weeks, caused decreased heart rate, as well as systolic and diastolic blood pressure levels(3).

The heart rate is controlled by neural as well as other factors (4). Hence a decrease in heart rate may be related to an increase in vagal tone, a decrease in cardiac sympathetic activity, as well as other, non- autonomic factors. In contrast, the heart rate variability (HRV) spectrum has been established as a probe of beat-to-beat autonomic control (5). The influences of the sympathetic and parasympathetic innervation on modulation of the heart rate are quantified by the power of the heart rate variability spectrum in specific frequency bands. Hence the present study aimed at analysing the heart rate variability spectrum related to the practice of both kapalabhati and nadisuddhi pranayama to get a better understanding about the immediate effects of these practices on the autonomic status.

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METHODS

Subjects

They were 12 normal, healthy male volunteers in the age range of 21 to 33 years (mean ± SD, 25.6 ± 3.1 years) who were familiar with both kapalabhati and nadisuddhi practices and had experience of the practices ranging from 6 months to 3 years (group average experience, 19.7 ± 12.8 months).

Design of the study

Recordings were made on separate days for the two different practices, maintaining the same time of recording of the day for each subject. The subject was seated in a dimly lit, sound attenuated chamber. Recordings, each lasting 5 min, were obtained before as well as immediately after each practice. The subject was seated in a comfortable sitting posture with the back straight, for both practices. The practices were performed at least 3 hours following the last meal.

Parameters studied

The electrocardiogram was recorded using standard bipolar limb lead 1 configuration and an AC amplifier with 1.5 Hz high pass filter and 75 Hz low pass filter setting (Medicaid, Chandigarh, India). The ECG was digitized using a 12 bit analog-to-digital convertor (ADC) at a sampling rate of 500 Hz and stored on the hard disk of a PC/ AT 486 system COMPTECH (Bangalore, India) for analysis (6). The R waves were detected to obtain a point event series of successive R-R intervals, from which the beat to beat heart rate series was computed. The data recorded were visually inspected off-line and only noise free data were included for analysis.

Frequency domain analysis

The mean values were removed from the heart rate series to obtain the HRV series. The HRV power spectrum was obtained using fast Fourier transform analysis (FFT). The energy in HRV series of the following specific frequency bands was studied, viz., the very low frequency component (0.0- 0.05Hz), low frequency component (0.05- 0.15 Hz), and high frequency component (0.15-0.50 Hz). The low frequency and high frequency values were expressed as normalized units (7).

Yoga practices

For the practice of rapid yoga breathing (kapalabhati), the subject was instructed to inhale deeply and start exhaling forcibly at the rate of 120 breath cycles per min (2.0Hz frequency). The rapid active exhalations are accomplished by rapid, forceful movements of the abdomen followed by passive, effortless inhalation. The duration of practice was prescribed as 1 min (8). Alternate nostril breathing (nadisuddhi pranayama) starts with exhalation through both nostrils, followed by closing the right nostril with the thumb of the right hand and inhaling slowly through the left nostril. After complete inhalation, the left nostril is closed with the little and ring fingers of the right hand followed by opening the right nostril and exhaling through it. The subject next inhales through the right nostril and then exhales through the left nostril. This forms one round of nadisuddhi pranayama. This was continued for fifteen minutes, which is the recommended duration of practice (8).

Statistics

The values of derived parameters obtained before the practices and the ones obtained after the practices were compared using the t-test for paired data.

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RESULTS

After kapalabhati, there was a significant reduction in high frequency power and an increase in low frequency power expressed in normalized units compared to the 'pre' value ($P<0.01$, paired 't' test in both cases). This contributed to a significant increase in low frequency/high frequency power ratio ($P<0.05$, paired 't' test, one tailed) following kapalabhati practice (Fig 1). Following nadisuddhi pranayama, there was no significant change, though a non-significant trend towards increase in high frequency power and low frequency power was observed (Fig 2). The baseline low frequency power value before nadisuddhi was higher than before kapalabhati ($P<0.05$).

TABLE 1: Heart rate variability spectral components measured pre and post high frequency (kapalabhati) and alternate nostril (nadisuddhi) breathing. Values are group mean ± SEM.

Practice	Low frequency Power (n. units)		High frequency Power (n. units)		Low frequency / High (n. units)	
	Pre	Post	Pre	Post	Pre	Post
Kapalabhati (n = 1 2)	35.4 ± 3.0	50.7 ± 6.8**	64.2 ± 3.0	49.3 ±6.8**	0.6 ±0.1	1.5± 0.5*
Nadisuddhi (n = 12)	49.3 ± 4.2	40.8 ± 6.9	49.9 ± 4.1	61.2 ±6.6	1.3 ±0.3	1.3 ± 0.6

*P< 0.05, **P<0.01, post versus pre, t- test for paired data.

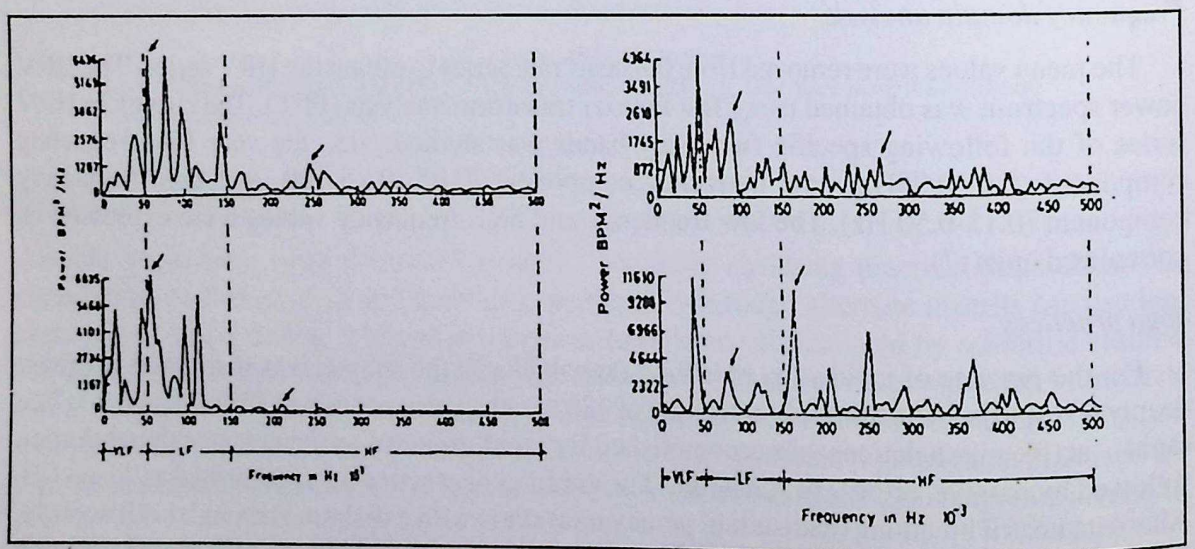

Fig.1: *Sample records of heart rate variability spectrum made before (upper record) and after (lower record) kapalabhati in a single subject (VN/31/ M). The vertical axis gives the power values in BPMI²/ Hz. The two vertical dotted lines separate the three frequency components, viz very low frequency (VLF), low frequency (LF) and high frequency (HF). The arrows indicate the highest peak in each range. The present record shows an increase in low frequency power and a decrease in high frequency power following kapalabhati, even though the actual scales (on the vertical axis) are different for the two records.*

Fig. 2: *Sample records of heart rate variability spectrum made before (upper record) and after (lower record) nadisuddhi pranayama in a single subject (VN/31/M). The details of the records are the same as for Fig 1. The present record shows an increase in high frequency power as well as a smaller increase in low frequency power following nadisuddhi pranayama, even though the actual scales (on the vertical axis) are different for the two records.*

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However, the baseline high frequency power before nadisuddhi was lower than that before kapalabhati ($P<0.05$).

The heart rate did not show a significant change after either practice. The group average values ± SEM are given in Table 1.

DISCUSSION

In the present study, following the practice of very rapid yoga breathing, there was an increase in the low frequency power, decrease in the high frequency power and an increase in the low frequency / high frequency power ratio (Table 1). There was no significant change following nadisuddhi pranayama. Also, the mean heart rate did not change following either Practice. There were baseline differences between low and high frequency power values for the two sessions.

The low frequency band (0.05-0.15Hz) of the heart rate variability spectrum is thought to correspond to sympathetic modulation, especially when expressed as normalized as opposed to absolute units (7). The representation of low frequency and high frequency energy values in normalized units expresses the degree of control exerted and the relative balance of the two branches of the autonomic nervous system. The efferent vagal activity is a major contributor to the high frequency band (0.15-0.50Hz). The low frequency / high frequency ratio is correlated with the sympathovagal balance (9).

Hence the present results suggest that the practice of kapalabhati shifts the sympathovagal balance towards sympathetic activation. Following nadisuddhi pranayama, the change is not as clear, though there appears to be an increased activation of both components.

The differences in baseline values could not be explained. Recordings of kapalabhati and nadisuddhi on each subject were made on separate days at the same time of the day. There was no fixed order for the two types of sessions on different days. However, at the start of each session, subjects were told the practice which was to the tested on that day. It is not known whether this influenced their baseline levels of autonomic activity. In order to understand the contribution of the differences in baseline values to the nature of change following either practice, separate calculations were made as described below. The percentage change in the five *lowest* values of the baseline low frequency (LF) component preceding kapalabhati and the five highest baseline LF values preceding nadisuddhi were calculated. Following kapalabhati, the percentage change was 8.9% for these 5 values. Since the average percentage change for the LF component of the 12 subjects was 43.2%, this suggested that the baseline low values of the LF component preceding kapalabhati did not correlate with the increase in this component following the practice. In contrast, following nadisuddhi for the 5 subjects with *highest* LF values preceding the practice, the percentage change was 45.3% (decrease). Since the average percentage change for the LF component of the 12 subjects was 15.5% (decrease), this suggested that the baseline high values of the LF component preceding nadisuddhi was correlated with the decrease in this component following the practice.

While attempting to explain the mechanisms underlying the changes, the respiratory sinus arrhythmia has to be taken into account. At typical respiratory frequencies near 0.20Hz (12 breath cycles per minute), the heart rate increases simultaneously with inspiration (10). Most investigators have found that cardiac vagal efferents are involved in mediating the heart rate fluctuations that occur with respiration at this frequency. It was also observed that the modulation of cardiac sympathetic efferents also plays a role in generating respiratory sinus arrhythmia at lower respiratory frequencies below 0.15Hz (9 breath cycles per min). Separate polygraph recordings of respiration

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showed that the breath rate values before and after kapalabhati as well as before and after nadisuddhi practice were in the range of 0.20-0.26Hz (11). Within this frequency, the respiratory sinus arrhythmia is correlated with vagal activity. Hence the increase in cardiosympathetic tone following kapalabhati is probably due to other factors. In response to variations in breathing patterns a number of central and autonomic nervous system mechanisms as well as mechanical (heart) and haemodynamic adjustments are triggered, thereby causing both tonic and phasic change in cardiovascular functioning (12).

An association between high frequency breathing and cardiovascular sympathetic activation was demonstrated in an earlier study (2) which reported an increase in heart rate and systolic blood pressure following the practice. However there are two main differences between the present study and the earlier one. In the previous study, there was no change in the frequency components of the heart rate variability spectrum, while the heart rate increased. These changes were reported during the practice, whereas in the present study, the effects reported apply to the period immediately after the practice. The differences may also be related to the fact that subjects of the earlier study practised kapalabhati for three 5 minute periods, whereas in the present study the duration of practice was 1 minute in keeping with yoga texts (8).

The absence of change following nadisuddhi pranayama, compared to the earlier report (3), could be due to the fact that the earlier study described baseline changes after 4 weeks of practice, whereas in the present study, the immediate effect was assessed

This difference between the factors determining the changes in heart rate versus changes in the heart rate variability spectral components is already known (4). Additional factors influence the heart rate compared to the HRV. Since the heart rate variability spectral components are determined by the autonomic nervous system, measurement of the heart rate variability may have greater application in assessing autonomic status than recording of heart rate alone. This application has been highlighted in the present study.

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Indian J Physiol Pharmacol 1993; 37(4): 350-352

LETTERS TO THE EDITOR

COMMENTS ON THE ARTICLES ON YOGA

(Received on 28 January, 1993)

Sir,

I would like to comment on three articles on yoga published recently in IJPP.

Regarding the article on the effect of yoga on reaction time, respiratory endurance and muscular strength (1) :

1. The names of asanas like Navasan, Naukasan and Mukhabhastrika are not mentioned anywhere in the traditional texts on yoga.

2. The duration of 18 yoga exercises was 30 min and the total practice session was also held for 30 min. How was this done? Was there no interval at all between exercises?

3. A control group should have been studied and matched for such parameters which are dependent upon age and since the pre and post measurements are separated by 3 months.

Regarding the letter on heart rate alterations in pranayamas (2):

1. Names of Pranayama have no traditional support from ancient texts, except Nadisuddhi Pranayama. The readers will therefore have no idea about the technique of Vibhaga, Mahat Yoga and Savitri Pranayama.

2. If a person is well trained and has been practising for 4 years, heart rate should not increase so much. Marginal increase of 5 to 7 beats/min is understandable. That means the present subject was practising with muscular exertion.

3. The ratios given for Vibhaga and Mahat yoga are objectionable; i.e., 1: 1:0.20 and 1:1:0.25 respectively. The traditional ratios are 1:2:2, 1:4:2 (Hathapradipika) and 6:8:5 (Goraksha Samhita Ch. II : 4) for Purak, Kumbhak and Rechak.

Regarding the letter on heart rate and respiratory changes accompanying single thought and thought less states (3) :

1. How did the investigator confirm whether the subject was really in "single thought" or "no thought" state of mind? Thoughtless condition is almost difficult to achieve since it is related to the degree of arousal of the brain.

2. From the respirogram it appears that the subject was not in the "No thought" state because mainly the expiratory phase of the respiratory cycle is seen disturbed, indicating cortical interference in the autonomic function. In single thought at least it is minimum.

3. The scale of 20 sec given in the graph and rate of respiration given in the Table do not correspond. From the scale it seems to be 12/min in normal, 8/min in the first single thought state, (upper line), 10/min in next single thought state (third line) and 7 to 11/min in 'no thought' state. Increased respiratory rate and decreased amplitude indicate sympathetic predominance and an anxious state of mind.

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2. Telles S, Desiraju T. Heart rate alterations in different types of pranayamas. *Indian J Physiol Pharmacol* 1992; 36: 287-288.

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Indian J Physiol Pharmacol 1993; 37(4)

LETTER TO THE EDITOR

DR. MADANAMOHAN'S REPLY

(Received on April 10, 1993)

Sir,

We are thankful to Dr. Gore for his reaction to our paper (1). We give our point-by- point response to his comments.

1. The techniques of Navasan, Navakasan and Mukhabhastrika are give on pages 80, 76 and A-77 respectively of "Yoga: Step-by-step" by Gitananda Swami (2). Yogeswar describes Navasan as Naukasanasupine and Navakasan as Naukasana-prone (3). Navakasan is described as Naukasan in Yogasan Vijnan by Dhirendre Brahmachari (4). We have followed the method and terminology given by Gitananda Swami(2). In brief, Navasan is assumed from the supine position by raising the upper part of the body and the legs on an incoming breath so that the toes are in line with the nose. The resultant boat-like posture is maintained for the required duration. Navakasan is the opposite posture of Navasan and is assumed from the prone position. Mukhabhastrika, a bellows type breathing is done by taking in a full breath and blasting out the air in short, repetitive 'whooshes' while the lips are pursed(in 'kaakimudraa').

2. The different yoga techniques followed each other without any rest period between them. An interval of a few seconds between the postures does not make any significant difference.

3. We agree that it would have been ideal to have a control group. However, while one can have any number of experimental animals like rats, it is difficult to get healthy, cooperating volunteers for control study. The period of yoga training was only 3 months and the subjects formed their own control. Hence a separate control group was not incorporated. The magnitude of changes observed in our study is so large that these cannot be attributed to factors other than the experimental intervention which was yoga in the present study. We do not expect changes in reaction time, respiratory pressure and breath holding time with increase in age (3 months in our study).

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Indian J Physiol Pharmacol 1993; 37(4)

LETTER TO THE EDITOR

DR. SHIRLEY TELLES REPLY

(Received on April 12, 1993)

Sir,

Regarding our letter on heart rate alterations in pranayamas (1):

1. Pranayama has been described as voluntary regulation of breathing (more often slowing down) which ultimately achieves a calm state of mind. In Savitri pranayama the subject strives to regulate the ratios (inhale: End-inspiratory Kumbhak: expiration: end-expiratory Kumbhak) as 2:1:2:1. In Mahat Yoga and Vibhaga pranayamas there is virtually no emphasis on the ratios. Breathing is expected to be slow and rhythmic.

We found that the pattern was consistent and there was no attempt to consciously regulate it. In Mahatyoga the mind was allowed to be engaged in thoughts of union of self with the Supreme, whereas in Vibhaga Pranayama the attention was focused on three different (imaginary) sectors of the lungs i.e., upper, middle, and lower.

2. It is possible that in spite of having more than five years' experience, the subject was practising Pranayama with muscular exertion.

3. As mentioned in the first response Vibhaga and Mahat Yoga Pranayamas were not similar to the traditional pranayamas (with ratios 1:2:2 or 1:4:2).

Regarding our letter on heart rate and respiratory changes accompanying single thought and thoughtless states (2) :

1. Studies by Roland and Friberg (3) have reported changes in regional cerebral blood flow with different types of targetted thinking (e.g. mentally tracing a route or repeating silently a meaningless jingle). In the absence of such facilities, other measures such as recording the cerebral evoked potentials would have given only a very gross neural correlate of the state of thinking since the neural generators of middle and long latency evoked potentials are still poorly understood. Hence, in the study reported, we relied wholly on the subjective report of the Yoga practitioner.

2. The comment "because mainly the expiratory phase of respiratory cycle is seen disturbed, indicating cortical interference in autonomic function" is not entirely logical. Voluntary control can be expected to alter either the inspiratory and or the expiratory phase of respiration. Quite apart from this, it is reasonable to assume that changes in neural activity related to thinking (or a thoughtless state) would influence other parts of the brain, and possibly alter the respiration. It would be very unusual to expect that a 'no thought state' would occur simultaneously with an absence of cerebral activity.

3. It may be pointed out that the graph gave only one representative sample of the respirogram recorded during 'no thought' and 'single thought' states. In contrast, values shown in the Table were mean values ± S.D.

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Neurology India, 47, September 1999

LETTER TO EDITOR

TRANSCRANIAL DOPPLER STUDIES OF MIDDLE CEREBRAL ARTERY BLOOD FLOW FOLLOWING DIFFERENT TEST CONDITIONS

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Transcranial Doppler ultrasound (TCD) is a noninvasive method of studying cerebral haemodynamics allowing the measurement of blood velocity in the major intracranial vessels using ultrasound signals transmitted through bone[1]. Cerebral circulation is controlled mainly by auto regulation and fluctuations in blood CO_2 and O_2 with scarcely any chances when arterial pressure is constant between 50 and 140mmHg[2]. We recorded the blood velocity in both right and left middle cerebral arteries (MCA) in a 26 year old male volunteer with TCD (DWL Ultrasonic Doppler System, Sipplingen, Germany). There were six repetitions on each side, and recordings were made before and immediately after breath holding, Valsalva maneuver, mental arithmetic, mental route finding, a yoga rapid shallow breathing at 120 times per minute and hyperventilation. A 2 MHz doppler probe, connected to a TCD device was mounted at a 30 degree angle over the squamous temporal bone using an elastic head band. The high pass filter was 250 Hz with emitted ultrasonic power of 56.0 mW.

There was a significant increase in systolic and diastolic blood flow velocity (sbfv, dbfv) following valsalva maneuver for both right and left MCA ($P<.005$, t test for paired data in all comparisons against the preceding baseline). In contrast following hyperventilation and rapid yoga breathing there was a significant decrease in dbfv for the right MCA ($P<.002$, both cases). Following, Hyperventilation the sbfv of the left MCA reduced ($P<.001$). There were no changes following breath holding, isometric contraction, mental arithmetic and mental route finding. An increase in blood flow velocity may be correlated with increased cerebral blood flow or reduced vessel diameter.[3] Immediately after the valsalva maneuver the systemic blood pressure has been reported to be approximately 170 mmHg[4]. As the BP rises above 140 mmHg, cerebral blood flow is known to increase as was demonstrated here by increased bfv. Breath holding may not have increased systemic BP to the same extent as valsalva, hence not influencing cerebral blood flow. Hyperventilation is known to reduce CO_2 in the blood and hence cerebral blood flow would reduce,[1] this was reflected in reduced bfv. The same result followed rapid yoga breathing, suggesting that this practice, like hyperventilation, reduces cerebral blood flow, possibly also by carbondioxide washout.

Hence TCD appears to allow simple, rapid and repeatable measures of changes in cerebral blood flow related to changes in systemic pressure and blood CO_2. In the present study changes in cerebral blood flow related to cognitive activities (such as mental route finding) were not recorded.

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Proceedings of the National Conference on Biomedical Engineering. pp 118-120

AMPLIFIER SETTINGS AND THE RECORDING OF THE ENDOSOMATIC SYMPATHETIC SKIN RESPONSE

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Abtract: The sympathetic skin response (SSR) is a measure of the electrodermal activity recorded by an endosomatic method, i.e., without using external current. It correlates with exogenous (e.g., a sound) and endogenous (e.g., a deep breath) stimuli. This paper describes the variations in the SSR waveform with varied amplifier filter settings (low cut filter settings 0.1 Hz, 0.3 Hz, and 5.0 Hz and high cut filter settings 15 HZ, 35 Hz, and 75 Hz) in 25 healthy male volunteers (aged between 20 and 40 years); under different physiological conditions (e.g., deep breathing and with successive sound stimuli). The optimal amplifier settings for psychophysiological studies using the SSR are discussed.

INTRODUCTION

The sympathetic skin response (SSR) is a slow wave, generated in deep layers of the skin, resulting from reflex activation of the sudomotor sympathetic efferent fibers. This slow galvanic reflex response is known to occur following a deep breath, an unexpected or arousing stimulus [1]. Its possible clinical uses in the diagnosis of autonomic disorders in both central and peripheral neuropathies, is gaining importance. As the spontaneous response and that to endogenous stimuli is a relatively new, inadequately worked out parameter in neurological studies, the amplifier filter settings for optimal recording were evaluated in the present study.

The component in equipment that eliminates unwanted frequencies is a filter [2]. A high frequency filter will affect the designated frequency by 20 or 30 percent and is expected to affect frequencies slower than the designated at a progressively lesser degree until there is no attenuation at all. In contrast frequencies above the designated filter will have progressively more than 20 or 30 percent attenuation so that in all cases some higher frequencies will be attenuated and be eliminated.

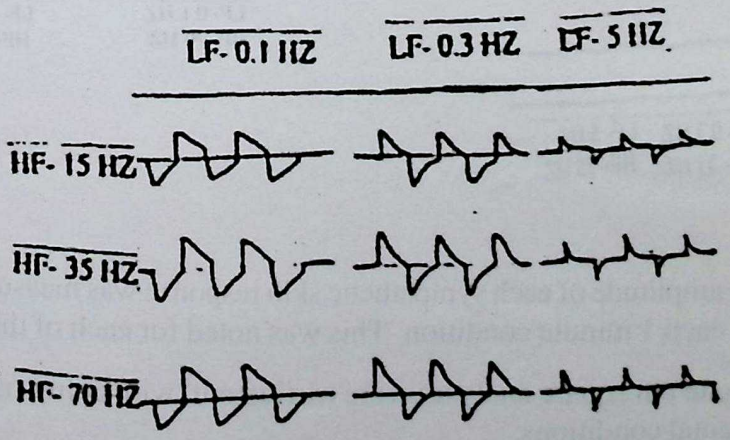

Fig.1 Calibration

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The terms time constant and low linear frequency are used interchangeably in considering the effect on slow activity, but the number is not the same where the terms are varied. A time constant of 1 sec represents a low linear frequency filter of 0.1 Hz. It is understood that the low frequency filter attenuates rather than eliminates low frequencies.

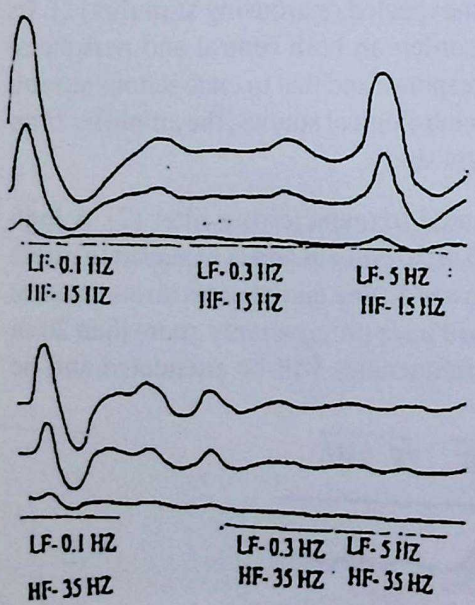
The present study assessed the SSR in normal volunteers during baseline conditions, while breathing deeply, and when given auditory stimuli. The filter settings were varied and the optimal SSR, with respect to number of responses and maximum amplitude was determined.

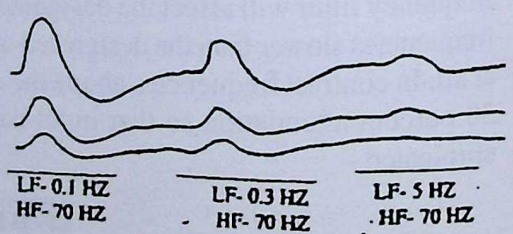
METHODS

Subjects: There were 25 normal healthy volunteers, all males with ages between 20.0 and 32.0 years (mean ± SD, 26.2 ± 3.4 years).

Design of the study: Each subject was assessed with different filter (low frequency or LF and high frequency or HF) settings, viz.I: LF 0.1 HF 15, LF 0.3 HF 15, LF 5.0 HF 15; II: LF 0.1 HF 35, LF 0.3 HF 35, LF 5.0 HF 35; and III: LF 0.1 HF 75, LF 0.3 HF 75. LF 5.0 HF 75. With each filter setting recordings were made in the baseline state (1 minute), during slow and deep breathing (1 minute), and while receiving 4 auditory stimuli, spaced 15 seconds apart (1 minute), making a total of 9 minutes.

Recording procedure: The sympathetic skin response was recorded using two Ag/AgCl disc electrodes filled with conducting paste, and placed on palmar and dorsal surfaces, over the hypothenar eminence. A ground electrode was placed on the right ankle above the medial malleolus. The electrodes were connected to an AC bioamplifier.





Data extraction: The amplitude of each sympathetic skin response was measured, also the number of SSR responses in each 1 minute condition. This was noted for each of the filter settings.

Data analysis: Separate chi square analyses were carried out, with columns = filter conditions, and rows = experimental conditions.

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YOGA FOR REHABILITATION

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RESULTS

The 3 X 3 chi square analysis showed significant difference between maximum amplitude recorded with different filter settings during the three conditions for low frequency filters 0.1, 0.3 and 5.0, with high frequency filter at 35 Hz [chi square = 13.98, df = 4, p <.01]. The same was also seen when the high cut filter was 70 Hz [chi square = 15.17, df = 4, p <.005]. It is apparent in the table (1) that maximum amplitude was seen with LF 0.1 Hz and HF = 70 Hz.

Table 1. Maximum Amplitude (mv) of SSR.

(A) HF - 35 Hz and (B) - 70Hz

Conditions	Low frequency filter (LF)		
	0.1	0.3	0.5
A: HF - 35Hz			
Base line	0.86	0.56	0.20
Deep breathing	1.06	0.75	0.25
Aud. stimuli	0.90	0.63	0.25
B: HF - 70Hz			
Base line	0.68	0.45	0.14
Deep breathing	0.12	0.80	0.24
Aud. stimuli	0.12	0.75	0.17

DISCUSSION

The sympathetic skin response is a slow reflex response to internal and external stimuli. It is gaining importance in neurological investigations. The present study showed that maximum amplitude was seen with LF 0.1 Hz and HF = 70 Hz. However, being a slow response the HF filter was of less importance and even with a HF of 15 Hz a good response was seen (Figure 1), though at HF = 15 Hz there were no significant differences between the maximum amplitudes for the three LF settings. Care should be taken to avoid high frequency artifact contamination (e.g., EMG) if HF = 35 or 70 Hz is used.

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YOGA FOR REHABILITATION - AN OVERVIEW

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Yoga is an ancient Indian science and way of life. The practice of yoga has been shown to be therapeutically useful in bronchial asthma,[1,2] type II diabetes Mellitus,[3,4] hypertension,[5] as well as other Psychosomatic ailments. The practice of yoga can also play a role in the rehabilitation of physically and mentally handicapped persons, as well as those who are socially disadvantaged.

Mentally handicapped subjects

A single case study showed that a mentally retarded woman (I.Q. = 41, on standard testing) was able to learn transcendental meditation (TM), which she practiced under close supervision for 14 months.[4] This brought about significant improvements in her speech, behaviour, and social skills, though her I.Q. remained unchanged. A controlled study was carried out on 90 mentally retarded children, randomly assigned the children to two groups (yoga, control) so that there were equal numbers of mild, moderate and severely retarded children in both groups.[7] The study assessed the effects of yoga practices (breathing exercises, pranayamas, loosening exercises, suryanamaskar, asanas and meditation) for a year. The moderately retarded among the yoga group performed significantly better on testing with the Binet-Kamat test (for general mental ability), Seguin form board (for co-ordination), and in the Vineland social maturity scale (to assess social adjustment and behaviour). Compared to their initial performance, as well as to that of the control group. The mild and severely retarded subjects of the yoga group had another benefit: they showed no deterioration in any score, where as the mildly retarded subjects of the control group showed negative scores on retesting. Hence yoga practices, including meditation are useful in the rehabilitation of the mentally handicapped.

Visually handicapped subjects:

Persons with impaired vision understandably often have higher levels of anxiety than those with normal vision. It has been shown that blind children learn yoga asanas with great ease. In a controlled study, it was shown that following three weeks of yoga practice (asanas and breathing practices), blind children had a significant decrease in breath rate and their abnormally irregular breathing became regular (reduced physiological signs of stress). There is also another possible area where the practice of yoga may benefit the blind. The blind are known to have a significantly better developed tactile sense than subjects with normal vision. Unfortunately this does not apply to their performance of motor skills,[10] which are increasingly required today, for example to use the specially designed computer keyboards. Yoga practices help in the development of motor skills in persons with normal vision, [11] so a similar effect may be obtained in the blind. This is currently under investigation.

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PHYSICALLY HANDICAPPED SUBJECTS

It was reported that 1.8% of the total Indian population had locomotor disorders such as those resulting from poliomyelitis. Deformities were found to occur in 53.3% of sufferers from rural areas. Certain yoga asanas (e.g. paschimottanasana and ushtrasana) were found to be useful by causing repeated stretching of tightened muscles. Similarly. Yogic sithilikaran vyayama (loosening exercises) helped patients with finger deformities due to rheumatoid arthritis, to regain some degree of function, e.g. in grasping.[13]

PRISIONERS (JAIL) AND CHILDREN IN A REMAND HOME

Jail inmates who were given training yoga experienced significant benefits.[14] This was based on their self report (better appetite, sleep and well being), as well as reports of the prison wardens.

Children who were committed to legal custody in a state remand home had signs of high physiological anxiety (higher heart and breath rates, and lower skin resistance), compared to children of the same age who were staying at home.[15] After six months of practising yoga with an emphasis on relaxation and awareness, the children showed significant improvement (reduced heart and breath rates, and an increase in skin resistance).

In contrast, a matched group of children who had a physical activity program during the allotted time, for the six month period, showed no such change in breath rate for skin resistance. Hence yoga practice is a useful addition to the routine of prisoners or of young people in a remand home. It may help reduce their stress and anxiety levels, improve their physical fitness, and perhaps even help in their social and moral rehabilitation. However, the last has yet to be tested.

Substance abuse

The practice of transcendental meditation (TM) was reported to improve inner control, decrease anxiety and strengthen the mental resolve. This was based on a retrospective study on 1862 persons who practised TM for an average of 20 months and showed a significant decrease in their consumption of marijuana, and a non significant trend of decrease in the abuse of amphetamines, barbiturates, LSD and narcotics.[14] A combination of yogasanas, pranayamas and meditation practised by chronic alcoholics for 3 months was found to cause significant changes in psychological and biochemical (e.g. plasma cortisol) parameters, which are known to be abnormal in chronic alcoholism.[12] Hence, following a period of deaddiction, yoga practice may contribute significantly to the rehabilitation of alcoholics as well as persons addicted to other substances.

Coronary artery disease

A combination of stress management through stretching exercises, meditation and visualization, along with dietary changes helped in the rehabilitation of patients with coronary artery disease.[18] After 24 days of this program, patients showed a 44% mean increase in duration of exercise, a 55% mean increase in total work performed, improved left ventricular regional wall motion during peak exercise, and a net change in left ventricular ejection fraction from rest to maximum exercise of +6.4%. There was 20.5%, mean decrease in plasma cholesterol levels and a 91.0% mean reduction in frequency of anginal episodes. Hence the practice of exercises, and meditation along with diet modification helps in the rehabilitation of patients with coronary artery disease, increasing their ability to perform exercise and work.

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HIV Positve and Aids Patients

A pilot study conducted on HIV positive persons,[19] showed that the. practice of Transcendental Meditation improved the health status and general well being while the immune status did not change. The practice of meditation and other yoga techniques may help in improving the psychological status of HIV positive persons.

SUMMARY

The use of yoga for rehabilitation has diverse applications. Yoga practice benefited mentally handicapped subjects by improving their mental ability, also the motor cordination and social skills. Physically handicapped subjects had a restoration of some degree of functional ability after practicing yoga. Visually impaired children showed a significant decrease in their abnormal anxiety levels when they practiced yoga for three weeks, while a program of physical activity had no such effect. Socially disadvantaged adults (prisoners in a jail) and children in a remand home showed significant improvement in sleep, appetite and general well being, as well as a decrease in physiological arousal. The practice of meditation was reported to decrease the degree of substance (marijuana) abuse, by strengthening in them the mental resolve and decreasing the anxiety. Another important area is the application of yoga (and indeed, lifestyle change), in the rehabilitation of patients with coronary artery disease. Finally, the possible role of yoga in improving the mental state and general wel1 being of HIV positive persons and patients with AIDS, is being explored.

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THE INTEGRATED APPROACH OF YOGA: A THERAPEUTIC TOOL FOR MENTALLY RETARDED CHILDREN: A ONE-YEAR CONTROLLED STUDY

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Abstract: Ninety children with mental retardation of mild, moderate and severe degree were selected from four special schools in Bangalore, India. Forty-five children underwent yogic training for one academic year (5h in every week) with an integrated set of yogic practices, including breathing exercises and *pranayama, sithilikarana* vyayama (loosening exercises), suryanamaskar, yogasanas and *meditation.* They were compared before and after yogic training with a control group of 45 mentally retarded children matched for chronological age, sex, IQ, socio-economic status and socio environmental background who were not exposed to yoga training but continued their usual school routine during that period. There was highly significant improvement in the IQ and social adaptation parameters in the yoga group as compared to the control group. This study shows the efficacy of yoga as an effective therapeutic tool in the management of mentally retarded children.

INTRODUCTION

Yoga therapy is fast advancing as an effective therapeutic tool in many physical, psychological and psychosomatic disorders (Nagarathna & Nagendra, 1983; Nagendra, 1984a, b; Digambarji Swami, 1975; Goyeche, 1979; Kuvalayananda Swami, 1983; Linden, 1973; Vahia *et al.,* 1973; Nagarathna & Nagendra, 1985). There have been subjective accounts and documented reports (Krishnamacharya Yoga Mandiram, 1983) on the efficacy of yoga therapy in the mentally retarded, but attempts at scientific validation are not yet available in the literature.

A controlled pilot study conducted by the present authors in 1984 on 10 children, for a period of Six months, indicated the usefulness of yoga therapy in mentally retarded children (Uma *et al.,* 1988). Based on this experience, the present study has been undertaken. This matched, controlled study on 45 pairs of mentally retarded children in Bangalore, India, has been designed to examine the efficacy of yoga therapy in mental retardation with regard to intelligence and social adaptation.

SUBJECTS AND METHODS

Four special schools for mentally retarded children were selected in Bangalore city, one school providing services for the upper socio-economic and other three schools for the middle and lower socio-economic groups. These are day schools with regular teaching staff and offer educational and occupational facilities for the mild, moderate and severe categories of mentally retarded children (Table 1).

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Table 1 Details of Special for Mentally retarded children

SI.No.	School	No. of Children (pairs)	Socio- economic group
1.	Baldwin Opportunity School	11	Upper strata
2.	Mar Thomas Opportunity	17	Middle and lower strata
3.	Bala Mano Vikasa Kendra	13	Middle and lower strata
4.	Bathany's Opportunity School	4	Middle and lower strata

Table 2 shows details of 90 children who have been selected for the study satisfying the ICD 9 diagnostic criteria for mental retardation (WHO, 1975). Children of either sex were included, chronological age range being 6-16 years. Children with cerebral palsy, gross neurological problems, physical handicaps, autism, mutism and sensory deficiencies, such as blindness and deafness were excluded from the study. Those with severe behavioural problems like severe hyperkinetic syndrome were also excluded from the study. Amongst those who were included in the study 12 pairs belonged to the mild degree (IQ 50-70), 17 pairs belonged to the moderate degree (IQ 35-50) and 16 pairs belonged to the severe degree (Uma *et al.,* 1988) (IQ 20-34). They were classified into these groups based on Binet Kamat (BK) and Seguin Form Board (SFB) scores. Ten pairs mainly in the severely retarded category who were uncooperative for BK testing were assessed on SFB Vineland Social Maturity Score (VSMS) was used for testing of social age in all three categories.

The duration of treatment was for one academic year (10 months), 1 hour daily, 5 days a week.

The experimental yoga group and control group were selected and matched from the same school so that the two groups were subjected to the same socio Environmental background and hence results could be comparable. A one-to-one matching was done with regard to chronological age, sex and IQ. In the 45 matched pairs, one from each pair was randomly selected for training in yoga and the other served as a control (Table 2). The control group was not exposed to yogic practices. Six children dropped out of the study for various reasons.

Table 2 Details of Children

	Control			Yoga		
Total number of children	45			45		
Number of Boys	29			29		
Number of Girls	16			16		
Age (chronological) (years):						
Range	6.166 - 15.1			6.0833 - 15.5		
Average	10.79 ± 2.46			10.73 ± 2.70		
Levels of retardation	Mild	Moderate	Severe	Mild	Moderate	Severe
Binet Kamath and From Board Scores (pairs)	12	17	16	12	17	16

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Table 3 Psychological tests used for asessment of IQ adn social maturiry

SI.No.	Test	Description	Assessment
1.	Binet Kamath for General Mental Ability	Standardized for Indian children. Widely accepted	IQ (intelligence quotient)
2.	Seguin Form Board	Performance test	IQ and mental age
3.	Vineland Social Maturity Scale	Questionnaire administered to	(MA) SQ and SA (social quotient) and (social age)

Table 3 shows the details of the psychological instruments used for assessment of IQ and social behaviour. Both the yoga and control groups were assessed with these tools before the commencement of yoga therapy and one year later after the therapy. Assessments for both the groups were conducted by a trained and qualified psychologist. The psychologist was blind to the matching and was not involved in the training programme.

All children in the yoga group were taught a specially prepared integrated set of yogic practices consisting of the following: (1) breathing exercises, *pranayama (breath* slowing techniques) and *kapalabhati (a kriya* to cleanse the respiratory tract) (10 min); *(2) Sithilikarana*

Table 4 Effect of yoga on intelligence and social behaviour *

Parameters		n	Before	After	t - values	
Binet Kamath (IQ)	C	35	44.3 ± 16.1	44.0 ± 18.1	2.0	NS
	Y	35	46.6 ± 13.1	57.5 ± 17.0	6.7	**
	Y -C	32	1.44 ± 11.0	9.56 ± 10.49	5.27	**
Seguin Form Board	C	41	4.34 ± 2.01	4.56 ± 1.82	0.95	NS
Mental age	Y	40	4.47 ± 1.76	5.68 ± 2.26	5.56	**
	Y -C	37	0.26 ± 1.90	1.11 ± 2.09	3.83	*
Vineland Social	C	45	6.8 ± 2.6	6.7 ± 2.7	3.14	NS
Maturity Scale	Y	45	7.1 ± 2.7	7.6 ± 3.0	5.11	**
Social Age	Y -C	35	0.59 ± 2.10	1.17 ± 2.23	3.14	**

**C : Control group; Y: Yoga group; Y-C: difference between yoga and control groups *P < 0.001. **P<0.0. NS: not significant*

vyayama (yoga exercises to loosen the joints) and suryanamaskar (salutations to the sun by 12-count yoga postures) (10 min); (3) yogasanas: simple physical postures (in the standing, sitting, prone and supine positions) with smooth, comfortable bending movements and specific slow breathing procedures; the *asana* practices were performed with the subject maintaining the final posture with the body relaxed (35 min); *savasana* is performed last; (4) meditation (5 min). These practices were taught by competent and well-trained yoga instructors for a period of 1 h on every working day at the school premises. The children in the yoga group were taught 5 h of yoga in one week for a period of one year. During this yoga practice hour, the control group was engaged in their usual school routine by one of their regular school staff in a different room within the school premises. Apart from this 1 h of yoga, the yoga group was exposed to the same school curriculum as the control groups.

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Table 5 x^2 values for control and yoga group

Total No.		No. of improved Cases (%)		No. of steady and deteriorated Cases (%)		X^2 values	
Control							
BK	35	20	(57.1)	15	(42.9)	0.714	NS
SFB	42	17	(40.5)	25	(59.5)	1.52	NS
VSMS	45	25	(55.6)	20	(44.4)	0.555	NS
Yoga							
BK	35	31	(88.6)	4	(11.4)	19.34	*
SFB	41	28	(68.3)	13	(31.7)	5.49	NS
VSMS	45	27	(60)	18	(40)	1.80	NS

**P < 0.05. NS: not significant*

Table 6(a) Yoga and severity of retardation (BK and SFB results)

	Total	No. improved (%)	No. with change (%)	No. deteriorated (%)	X^2 value	
Control group						
Mild	12	3 (25)	2 (17)	7 (58)	3.0	NS
Moderate	17	9 (52)	1 (6.8)	7 (41.2)	NS	NS
Severe	16	6 (38)	8 (50)	7 (41.2)	NS	NS
Yoga group						
Mild	12	6 (50)	4 (34)	2 (16)	3.0	NS
Moderate	17	15 (88)	1 (6.1)	1 (5.9)	10.0*	
Severe	16	5 (33)	11(67)	0 (0)	2.25	NS

**P < 0.05. NS: not significant*

Attendance was recorded every day for both yoga and control groups and was found satisfactory.

RESULTS

Table 4 summarizes the results of the analysis of the pre and post data using the two- tailed Student's paired t-test, in all three parameters. The t-values for the control group show significant improvement in BK but no change in SFB and deterioration in VSMS scores. On the contrary, the yoga group portray highly significant improvements in all the three parameters studied. The result for (Y-C) also clearly bring about the usefulness of yoga compared to the control group by highly significant values of t.

Table 5 depicts the X^2 evaluation of results in both control and yoga groups. In the control group, there is no significant change in all three parameters. In the yoga group, the BK scores has significantly improved. Eighty-nine per cent improved their BK scores in the yoga group compared to 57% in the control group. Sixty-eight per cent enhanced their SFB capacities, as opposed to only 41% in the control group. Sixty per cent and 56% improved their VSMS scores in the yoga and control groups, respectively.

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Table 6(b) Yoga and range of change in IQ units and overall mean of range (BK Test)

	Mild		Moderate		Severe	
	Control	Yoga	Control	Yoga	Control	Yoga
Range of change of IQ	-12 to 14	-6 to14	-5 to 25	-4 to 25	-5 to 11	1 to 11
Overall mean of range (includes positive and negetive scores)	- 1.71	8.09	4.60	12.58	3.42	6.00

Table 6 (a & b) depicts the changes due to yoga intervention in the mild, moderate and severe degrees of MR. A x^2 evaluation based on two degrees of freedom (improved or non-improved cases including deterioration) is also seen in the last column. In the control group, there is no significant increase or decrease after the test period in all three categories. In the yoga group, there is significant improvement in the moderate degree group and no deterioration in other two categories.

The overall mean differences in units of IQ (BK scores) show improvement in all three categories of yoga group as compared to control group. In both groups, the moderate category shows a higher mean compared to the mild and severe, the yoga group mean being significantly higher than the control mean. There is no deterioration in any category in the yoga group whereas the mild degree in control group shows a negative score.

DISCUSSION

It is known that regular practice of yoga builds up the personality at all levels, i.e. physical, mental, intellectual and emotional, in normal persons (Udupa & Singh, 1972; Udupa *et al.,* 1973). The results from this study clearly show that children with mental retardation also improve considerably by yogic practices. It has been found especially useful in improving the intellectual performance and social adaptation in all three categories of retardation under study, more so in the moderate and mild groups. Epidemiological and hospital studies show that mild and moderate degree are more prevalent in India as compared to other categories (Gupta & Sethi, 1980; Prabhu, 1977). Therefore, it is of significance that it is these two groups which have been most benefited by yoga practices. The yoga techniques loosen the joints and relax the musculature and thus help the children in improving their locomotor skills and basic controls. Yoga brings control over breathing and that works in effectively increasing the psycho-motor coordination. Yoga is a conscious process of gaining control over the mind, and thus the concentration and attention-span improve, and hence both IQ and memory power will enhance. By improving skills and coordination

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SUDOMOTOR SYMPATHETIC HYPOFUNCTION IN DOWN'S SYNDROME

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Abstract : General sympathetic dysfunction has been proposed as an explanation for the inability to reach normal heightened attention in Down's syndrome (DS). The present study on 15 DS subjects (group average age ± SD, 14.3 ± 3.6 years; 11 males) and in an equal number of age - and gender - matched normal subjects (NS), evaluated activity in different subdivisions of the sympathetic nervous system. DS subjects had (i) lower skin conductance levels (i.e., lower sudomotor sympathetic activity) and (ii) higher heart rates than NS. In response to auditory stimuli, DS subjects showed abnormal SSR responses (also indicating sudomotor sympathetic activity) but normal cutaneous vasoconstriction. Hence the results suggest that sympathetic dysfunction in DS is restricted to the sudomotor subdivision, activity of which has been associated with attention and recognition.

Key words : *Down's syndrome; sudomotor sympathetic; autonomic dysfunction; focused attention.*

INTRODUCTION

Autonomic nervous system dysfunction is frequent in persons with Down's syndrome (DS) and is constituted mainly by an imbalance between sympathetic and vagal systems (1). Standard tests (i.e., postural change and the cold pressor test) revealed no differences between DS subjects and age matched controls, with respect to heart rate, BP, and plasma catacholamines (2). A decrease in heart rate variability and breath amplitude, which is normally associated with focused attention while on a task, was not seen in retardates, who showed an opposite trend, which is incompatible with sustained attention (3). Also, autonomic activity during the phases of sleep has been studied in DS to understand the greater incidence of central sleep apnoea in these persons (1). DS subjects showed lower sympathetic activity during REM sleep compared to control subjects (4). A series of studies reported by Luria in 1963 (5), suggested that mentally retarded children could be distinguished from non retarded children on the basis of the orienting response (OR). This "what is it?" response, reflects a very basic reaction to inputs from the surroundings. Some retarded individuals were shown to have unstable or weak OR, which, if they occurred, extinguished rapidly. Children with DS showed electrodermal hyporesponsivity in their ORs to auditory stimuli(6).

In the studies cited above (1-4), autonomic activity in the mentally retarded was described in relation to a task or a change in arousal, as in sleep. The present study compared autonomic and respiratory measures at baseline in subjects with DS compared with age-matched, normal subjects. Also, studies on habituation of the ORs (5-6) described changes in electrodermal reactivity (EDR). The present study reported responses of other autonomic measures (e.g., heart rate and cutaneous blood flow) during exposure to auditory stimuli, in subjects with DS.

METHODS

Subjects

Baseline autonomic measurements were made in 15 subjects (11 males) with DS(7), with group average age ± SD, 14.3 ± 3.6 years; and 15 age and sex matched normal subjects (NS). Also

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recordings were made in these 15 DS subjects and in another 10 DS subjects (n = 25; group average age ± SD, 17.0 ± 5.4 years; 19 males) to compare baseline recordings with those during exposure to auditory stimuli.

Assessment procedure

During assessments subjects were seated erect, with back support, in a dimly lit, sound attenuated recording room. Autonomic and respiratory measures were recorded with a 4-channel polygraph (Medicaid, Chandigarh, India) in 5-minute periods (baseline and during auditory stimuli). The EKG was recorded using standard limb lead 1 configuration. The skin conductance level (SCL) was recorded using Ag/AgCl electrodes covered with electrode jel and placed in contact with the volar surfaces of the distal phalanges of the index and middle fingers of the right hand. A low-level DC preamplifier was used and a constant voltage of 0.5V was passed between the electrodes. The respiration was recorded using a nasal thermistor clipped at the more patent nostril. The spontaneous sympathetic skin response (SSR) was recorded using Ag/AgCl electrodes filled with electrode gel (8). Electrodes were placed (a) on the back of the hand, in the second interosseous space, about 3-cm proximal to the interdigital web (b) on the palm of the hand. Amplifier settings were kept at: TC 0.1 ms, high cut filter at 70 Hz and sensitivity at 2 mV/cm.

Design

(i) To compare baseline differences between DS and NS, subjects were assessed in separate 10 minute sessions. (2) To study responses to auditory stimuli in DS subjects, the baseline period of 5 minutes was followed by another 5 minute period with 10 auditory stimuli spaced 30 seconds apart evenly, to elicit habituation.

Data extraction

The following data were extracted from the polygraph records: The respiratory rate (in cycles per minute) was calculated by counting the breath cycles in 60 second epochs, continuously. Finger plethysmogram amplitude (in mm) and skin conductance level (in μS) was sampled at 20-second intervals. Values averaged across each of the periods (before, after) of a session, were used for analysis. An SSR was said to occur as a response to the sound stimulus, if it occurred within 1 s and the amplitude was greater than 2000 μV.

Analysis

(i) Baseline data of DS and NS subjects were compared using the Student t-test for unpaired data. (ii) Data of the DS group (a) before and (b) during exposure to the stimuli were compared using the t-test for paired data. (iii) Number of DS subjects who showed habituation of the SSR to sound stimuli were compared to those who did not, using the McNemar test.

RESULTS

(1) Comparison of baseline autonomic measures between NS and DS (Table 1; n = 15 each; Student t-test for unpaired data): The skin conductance level (SCL) in μS was significantly lower in DS compared with NS (P<.01) and heart rate was significantly higher in DS (P<.01). (2) Comparison of autonomic measures in DS (n = 25) before (5 min) and during exposure to 10 auditory stimuli (5 min) (Table II). The finger plethysmogram amplitude was significantly lower during exposure to sound stimuli compared to before (P<.05). (3) Comparison of number of DS subjects who showed habituation of SSR to the stimuli versus those who did not habituate: The number of subjects who showed abnormal SSRs (i.e., did not show SSRs (n = 10) and no SSR

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Table I

Autonomic and respiratory measures in normal subjects (NS) and those with Down's syndrome (DS). Values are group mean (95% CI)

	NS (N = 15)	DS (N = 15)
Heart rate (bpm)	73.58 (69.76 - 77.40)	91.80** (80.04 - 103.56)
Breath rate (cpm)	21.5 (11.77 - 23.23)	22.8 (20.03 - 25.57)
Skin conductance(μS)	9.52 (6.82 - 12.22)	4.21** (1.27 - 2.65)

***IP<.01. DS versus NS. Student t test for unpaired data*

Table II

Autonomic and respiratory measures in Down's syndrome subjects (n = 25), at baseline (BL) and during auditory stimuli (ST). Values are Group Mean(95% CI)

	BL	ST
Heart rate (bpm)	88.39 (81.33 - 95.45)	87.18 (80.16 - 94.20)
Breath rate (cpm)	21.08 (19.30 - 22.86)	21.72 (20.16 - 23.28)
Skin conductance(μS)	4.77 (3.70 - 5.84)	4.36 (3.44 - 5.28)
Finger plethysmogram(mm)	1.65 (6.82 - 12.22)	1.25* (0.99 - 1.51)

**P<.05, Paired t test, ST versus BL*

habituation (n = 7), was not significantly different from the number of subjects who did habituate (n = 8), using the McNemar test (P>.05).

DISCUSSION

In the present study DS subjects showed lower SCL and higher heart rates, compared with age matched, normal subjects. Also, DS subjects showed a decrease in finger plethysmogram amplitude during exposure to auditory stimuli, but no other autonomic changes. Though more subjects showed abnormal SSRs to auditory stimuli, they were not significantly more than those who did habituate.

A lower SCL (higher skin resistance) is correlated with lower sympathetic sudomotor activity suggesting that baseline electrodermal responsivity is lower in DS as was described previously as part of the OR (5, 6). Some of the present DS subjects also showed abnormal SSRs to repeated auditory stimuli, with 10 subjects showing no habituation, 7 subjects showing no SSR, and 8 subjects showing the expected response, i.e., habituation.

The higher resting heart rate in DS and the reduction in finger plethysmogram amplitude (i.e., cutaneous vasoconstriction) (9) during auditory stimuli suggest that cardiovascular sympathetic tone is not lower, but possibly exaggerated in DS, which may be related to the hyperkinetic behaviour which is frequently associated with this syndrome (10). Also, our previous preliminary results (11), showed that the sole difference in the HRV spectrum components between DS and NS was that the HF component peak power was higher in DS. This suggests that activity in the HF band is well within the RSA (Respiratory Sinus Arrhythmia), vagal band of activity. However, this does not suggest any change in cardiac sympathetic-vagal balance.

Hence in DS, there appears to be selective reduction of sympathetic sudomotor activity with either no change or an increase in cardiovascular sympathetic activity. This is in keeping with the accepted idea that different subdivisions of the sympathetic nervous system may be active differently (12). The inadequate sympathetic activity in some subdivision (i.e., sudomotor) in DS may explain the inability of these subjects to focus attention. Electrodermal activity has already been reported to be abnormal in subjects who lose their ability to attend to and recognize familiar information (13). Hence the sudomotor dysfunction in DS may be related to the inability of these persons to

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focus attention and learn normally, especially since recognition and recall are essential to learning and memory (14).

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MIDDLE LATENCY AUDITORY EVOKED POTENTIALS IN CONGENITALLY BLIND AND NORMAL SIGHTED SUBJECTS

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Middle latency auditory evoked potentials were recorded in two groups of ten subjects each, viz, congenitally blind (CB) and age-matched subjects with normal vision (NV). The age range for both groups was 13 to 16 years. The CB group subject had peripheral deficits, with absence of visual evoked responses. The peak latency, of the Nb wave (the maximum negativity between 38 and 48 ms) was significantly lower in the CB group compared to NV group ($P < .05$, one-tailed, two factor ANOVA, Tukey test). In addition to these recordings from the vertex, recordings were also made from occipital areas, to test whether the visual cortex contributes to information processing at primary auditory cortical levels in the blind, as was reported in earlier studies on the generation of potentials during auditory selective attention. No such effect was observed. Hence, it appears that in blind subjects changes in generators of auditory middle latency evoked potential, are mainly related to latency, rather than to scalp distribution of these components.

Keywords: *Middle latency auditory evoked potentials; congenitally blind; normal sighted, primary cortical areas.*

Blindness at an early stage of development has been found to modify nondeprived sensory modalities as a compensatory measure. A study of the long-latency auditory event related potentials (ERPs) in early blind humans showed that the negative deflection 100 ms from stimulus onset (NI) and subsequent deflections (P2 and P3) show shortened latencies and enhanced amplitudes (Niemeyer & Starlinger, 1981; Woods, Clayworth & Bach-y-Rita, 1985). In a subsequent study auditory ERPs were recorded in early blind subjects and sighted Controls when they attended to stimuli delivered to a designated ear under dichotic conditions (Alho, Kujala, Paavilainen, Summala & Naatanen, 1993). The scalp distribution of the processing negativity, i.e., the endogenous negativity elicited by attended stimuli, as well as the mismatch negativity elicited by occasional higher frequency tones, was recorded more posteriorly in the blind compared to the normal sighted. These results suggest that posterior brain areas normally involved in vision participate in auditory selective attention in the blind.

The present study was designed to compare: (1) the peak latencies and amplitudes of middle latency auditory evoked potential (AEP-MLR) components in blind and age-matched normal sighted subjects, also (2) the peak amplitudes of AEP-MLR components recorded from the conventional site (i.e., vertex) with recordings made from posterior brain areas (i.e., occiput). This comparison was made in both blind and normal-sighted subjects.

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METHOD

Subjects

There were two groups of ten subjects each. One group consisted of blind subjects (group average age ± SD, 14.3 ± 1.4 years), with a single female subject. All subjects had a diagnosed peripheral deficit with an inability to differentiate between light and dark, from birth. This was confirmed by an absence of visual ERPs to light flashes. Apart from visual impairment these subjects had no other physical or mental deficit. The other group consisted of subjects with normal vision without correction, confirmed by normal ERPs elicited by light flashes, who were selected to match the blind subjects for age (± 1 year). The group average age ± SD of this group was 14.1 ± 1.1 years. For both groups the informed consent of the subjects and their guardians was taken in accordance with the ethical guidelines of the Indian Council of Medical Research (New Delhi, India).

Design of the Study

All subjects were assessed in a single sitting. Recordings were made in the following sequence: two consecutive recordings (R1, R2) of AEP-MLR to assess the immediate reproducibility of the waveforms, followed by a recording of VEP.

Recording of Evoked Potentials

(1) Auditory middle latency evoked potentials (AEP-MLR) were recorded in the 100 ms postimulus time period, from Cz, referenced to the right ear lobe with the ground electrode on the forehead. The preamplifier band width was set at 10 to 1500 Hz. 1500 responses were averaged for each period. Sweeps containing artifactually large signals were rejected through software specification. The rejection level was expressed as a percentage of the full scale range of the analog-to-digital converter. This level was set at 85%. The number of sweeps was displayed on the monitor. Click stimuli of 40μs duration and alternating polarity were delivered at 5 Hz binaurally, through acoustically shielded earphones (Elga DR-531, Japan). The intensity was kept at 80 dB for all assessments. The threshold of hearing was also noted in all subjects.

Visual evoked potentials were recorded in the 200 ms poststimulus time period, from Oz, referenced to the right earlobe, with the ground electrode on the forehead. The preamplifier band width was set at 1 to 1 00 Hz and 1 00 responses were averaged for each period. Artifact rejection was similar to the method described above for recording auditory evoked potentials. Light flashes were given using a LED visual stimulator (Nihon Kohden SLS 3500). Stimuli were given to each eye separately and also binocularly.

AEP-MLRs Components

Peak amplitudes of short latency wave V, and middle latency Na, Pa and Nb waves were measured from the baseline existing it the beginning of the sweep. Peak latency was measured from the time of click delivery.

The middle latency auditory evoked response components (AEP-MLRs components) were described as follows: wave V was the maximum positive peak between 5 and 8 ms, the Na wave was the maximum negative peak between 14 and 18 ms, the maximum positive peak between the Na wave and 35 ms was described as the Pa wave, and the maximum negative peak between 38 and 48 ms was described as the Nb wave. These descriptions are similar to those in other studies on AEP-MLRs (Erwin & Buchwald, 1986; McPherson, Tures & Starr, 1989).

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Data Analysis

1. Comparison of peak latencies between congenitally blind subjects and those with normal vision. The data were analyzed using a two factor analysis of variance (ANOVA), with factor A = groups, i.e., congenitally blind versus normal vision, and factor B = repeat recordings (R1, R2). The Tukey multiple comparison test was used to detect significant differences between group mean values.

2. Comparison of peak amplitudes of potentials in congenitally blind subjects and those with normal vision using a two factor analysis of variance (ANOVA), with factor A = groups i.e., congenitally blind versus normal vision, and factor B=repeat recordings (RI, R2). Separate ANOVAs were performed for peak amplitudes of potentials recorded from the two sites, viz Cz and Oz. This analysis was restricted to the Pa and Nb waves, which are known to have cortical generators. The Tukey multiple comparison test was used to detect significant differences between group mean values.

RESULTS

[1] Comparison of peak latencies between congenitally blind subjects and those with normal vision showed a significant difference (two factor ANOVA) between the Nb wave peak latency (38 ms-48 ms range) of the two groups, viz., congenitally blind and normal sighted [F for Factor A = 5.35, since F.05 *(1)* 1,36 = 4.1 1, hence p < .05]. However, there was no significant difference between the repeat assessments, i.e., RI and R2, Factor B ($p > .50$), and the interaction between factors (A x B) was also not significant ($p > .10$). The F value for $df = 1.36$ has been derived by linear interpolation from the $df = 1.30$ and $df = 1.40$ from the standard table as has been described (Zar. 1984).

Also, the Tukey test for multiple comparisons between mean values showed a marginal significant difference between the mean values (second assessments) of the congenitally blind and normal sighted subjects [q = 3.65, since q at probability level .07 for df = 36, 4 = 3.62, hence $p < .07$]. The significantly lower Nb wave peak latency in the congenitally blind group was observed as: (1) a difference of more than 3.0 ms in 4 subjects, (2) more than 1.0 ms in 2 subjects, (3) in 3 subjects this difference was less marked (0.56 to 0.83 ms) and (4) in a single CB subject the Nb wave peak latency was higher (by 1.0 ms). Two examples of (1) and a single example of (3) are illustrated in Figure 1. The two factor ANOVA did not show significant differences between either factors or interactions for the peak latencies of the other AEP-MLRs component (p< .20, in all cases).

[2] Comparison of the peak amplitudes of the Pa and Nb waves recorded from the occipital area (Oz) showed that the peak amplitude of the Pa wave at Oz was significantly lower in the congenitally blind compared to the normal vision group [F for Factor A= 5.07, since F.05 *(1)* 1,36 = 4.11, hence p <.05]. There was no significant difference between repeat assessments or interaction between factors (Factors B, A x B, p > .20) for Pa wave. For the Nb wave there were also no sig- nificant differences (Factor A, Factor B, A x B, p > .50).

When recordings were made at Cz, there were no significant differences for all 4 auditory evoked potential components studied (p > .20, for all comparisons).

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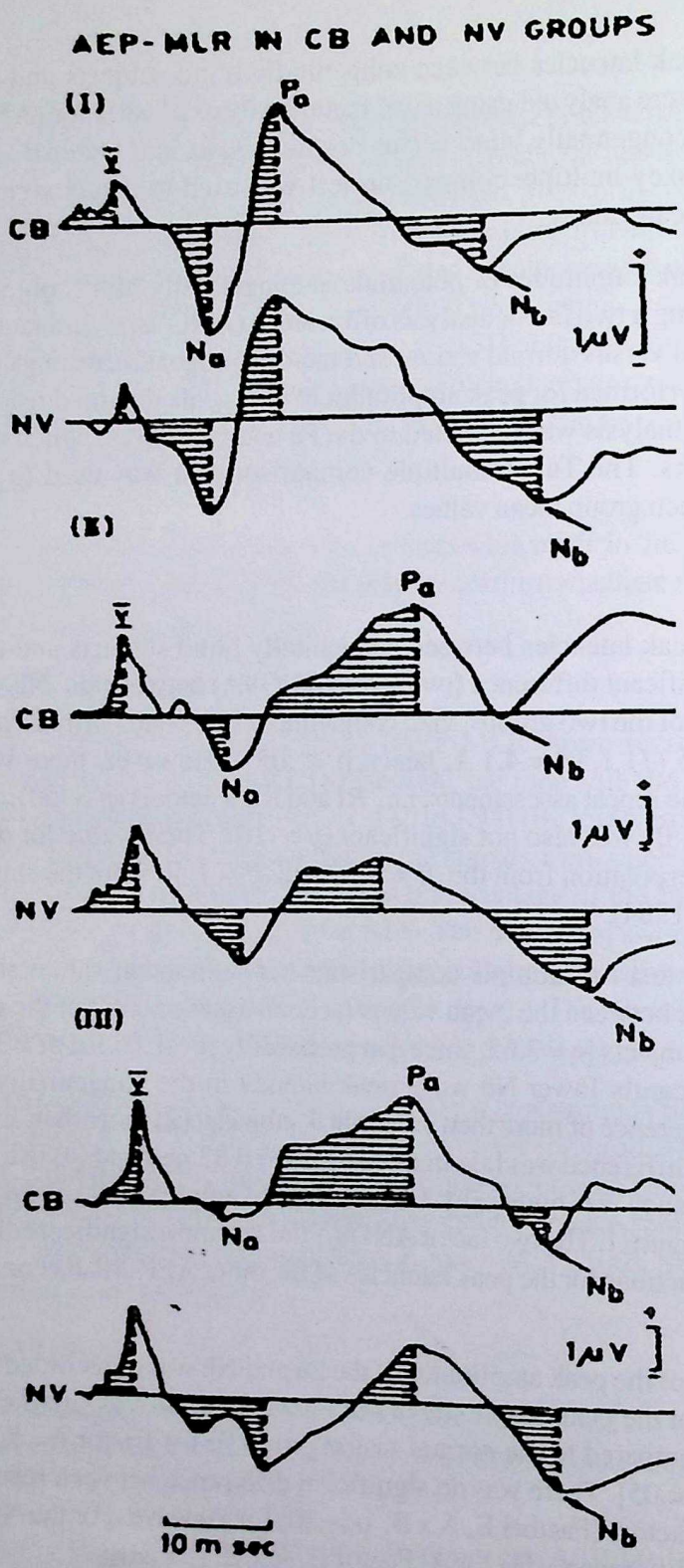

FIGURE 1: Three examples of AEP-MLRs recorded in three pairs of congenitally bling(CB) and normal vision(NV) subjects. The first two pairs (I,II) shows examples of noticeabley lower Nb wave peak latency in CB group subjects compared to NV group subjects. The third pair (III) shows a less obvious difference in Nb wave peak latency between the two groups.

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The group average values of peak amplitudes and latencies of the four components studied. for the congenitally blind and normal sighted subjects are given in Table 1.

TABLE 1: Peak latencies and peak ainplitudes of AEP-MLRs recorded in congenitally blind (CB) and normal vision (NV) subjects, (N = 1 0)

	Wave V		Na wave		Pa wave		Nb wave	
	CB	NV	CB	NV	CB	NV	CB	NV
Peak Latency (ms)	5.4 ±1.0	5.4 ±1.0	14.6 ±1.8	14.5 ±1.8	28.3 ±5.6	28.9 ±6.2	44.3* ±3.6	47.7 ±4.2
Peak Amplitude (uV) at Cz	1.2 ±0.5	1.2 ±0.6	0.7 ±0.8	1.9 ±1.3	1.1 ±0.9	1.2 ±1.0	1.1 ±0.5	1.3 ±0.8
Peak Amplitude (uV) at Oz	–	–	–	–	0.7* ±0.8	1.0 ±1.2	0.5 0.3	0.5 ±0.5

** P<.05, two factor ANOVA, One - tailed, CB versus NV*

DISCUSSION

The present results show that the Nb wave peak latency was significantly lower in congenitally blind (CB) subjects compared to age matched subjects with normal vision (NV). The peak amplitude of the Pa wave was significantly lower for the CB group compared to the NV group when the recording was made from Oz. There was no obvious difference in the threshold of hearing of CB and NV groups.

The lower peak latency of the Nb wave in the CB group is in keeping with previous reports of lower 1atency of the N1 wave in CB subjects (Niemeyer & Starlinger, 1981; Woods et al., 1985). However these reports also described enhanced amplitude in the blind. In the present study there was no significant difference in peak amplitudes of the two groups when recordings were made from the vertex (Cz). Another study (Alho et al., 1993), had described a larger processing negativity (PN) to attended tones at occipital scalp sites in CB subjects compared to subjects with normal vision. These results suggested that in blind subjects in addition to the participation of conventional neural areas (auditory cortex, frontal cortex) the parietal and even occipital cortices may contribute to the PN.

In the present results no such effects were observed. In fact the peak amplitude of the Pa wave recorded from the occipital area of the congenitally blind subjects was significantly less than that of the normal sighted subjects, recorded from the same site. The Pa wave is understood to be related to simultaneous activation of both supratemporal auditory cortices (Deiber, Ibanez, Fischer, Perrin & Mauguiere, 1988). Intracerebral recording in man has shown that the generator of the Nb wave is localized with relatively focal topology, in the dorsoposteromedial part of Heschl's gyrus, or primary auditory cortex (Liegeois-Chauvel, Musolino, Badier, Marquis & Chauvel, 1994). In the present study lower Nb wave peak 1atency in the blind implies that facilitation of processing of auditory information occurs at the level of the primary auditory cortex. The absence of change in the wave V and Na wave may mean that brainstem and diencephalic areas, which are known generators of these waves (Deiber et al., 1988), appear unchanged.

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The results of the present study also suggest that the occipital areas do not participate in the information processing at primary cortical areas. This result is in contrast to the previous study (Alho et al., 1993) which demonstrated participation of more posterior areas in generation of potentials during auditory selective attention.

The lower peak amplitude of the Pa wave recorded from Oz in the blind compared to the normal sighted is contrary to the above cited study (Alho et al., 1993). None of the blind subjects had central (cortical) blindness, making it unlikely that underlying neuropathology could explain the lower amplitude recorded at Oz in the CB group. Hence it appears as though the occipital area does not play a role ill auditory information processing at primary cortical areas, in the congenitally blind. Compensatory changes at this level occur as shortened latency of the corresponding components.

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SHORTER LATENCIES OF COMPONENTS OF MIDDLE LATENCY AUDITORY EVOKED POTENTIALS IN CONGENITALLY BLIND COMPARED TO NORMAL SIGHTED SUBJECTS

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A previous study which reported shorter latencies of the Nb component of AEP-MLRS in congenitally blind compared to normal sighted subjects, formed the basis for the present study. The blind subjects had received a rehabilitation program from the age of 4 years onwards, which may have influenced auditory function. Hence the present study was designed to compare the AEP MLRs of normal sighted subjects with age-matched blind subjects who had not undergone early rehabilitation. Auditory evoked potentials (0 to 100 ms. range) were recorded in 10 congenitally blind subjects (average age = 22.4 $\pm$ 4.9 yrs.) and an equal number of age matched subjects with normal vision. There were two repetitions per subject. The peak latencies of both the Pa (maximum positive peak between Na and 35 ms.) and Nb (maximum negative peak between 38 and 52 ms.) waves was significantly shorter in congenitally blind compared to normal sighted subjects. Since the Pa and Nb waves are believed to be generated by the superior temporal cortex (Heschl's gyrus), it appears that processing at this neural level occurs more efficiently in the blind. Also, in spite of the absence of an early rehabilitation program the present subjects showed the same auditory changes as those reported earlier.

Key words: *Middle latency auditory evoked potentials; congenitally blind; normal-sighted; primary auditory area; auditory inputs for rehabilitation.*

Impaired vision during early development has been shown to give rise to compensatory changes in the auditory system. Auditory perceptual sensitivity was modified in the congenitally blind, enabling them to use echoes to perceive spatial positions of objects (Strelow and Brabyn, 1982). Development of such abilities may be related to changes in auditory processing. For example, the long latency event related potential waves (NI, P2, and P3) were found to have shorter latencies and higher amplitudes in early blind humans compared to those with normal vision (Niemeyer and Starlinger, 1981). The Nb component of AEP-MLR (average peak latency 44.3ms) had a significantly shorter latency in congenitally blind persons (Naveen, Srinivas, Nirmala, Nagendra and Telles, 1997). This suggested that auditory information processing at the level of the posteromedial part of the primary auditory cortex, the known generator of the Nb wave (Liegeois-Chauvel, Musolino, Badier, Marquis and Chauvel, 1994) was more efficient in the blind.

Based on investigations of somatosensory information in the blind it was thought that adaptive changes may be enhanced by experience, such as Braille reading (Sadato, Pascual-Leone,

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Grafman, Ibanez, Deiber, Dold and Hallett, 1996). In the study on AEP-MLRs cited above (Naveen *et al.*, 1997), the subjects were all participating in a systematic education and rehabilitation program from the age of four years till the time of the study, when the group average age was 14.3 ± 1.4 years. The program included learning based on Braille reading and auditory inputs. This gave rise to the speculation that the rehabilitation program may have contributed to the adaptations seen in auditory functioning.

Hence the present study was designed to determine the changes in auditory function (measured through middle latency auditory evoked responses, AEP-MLRS) in congenitally blind subjects who had minimal, or no formal rehabilitation.

METHOD

Subjects

Two groups were studied with 10 subjects in each group, i.e., congenitally blind and normal vision. The congenitally blind subjects (group average age ± SD, 22.4 ± 4.9 years) had a diagnosed peripheral visual deficit from birth and no other abnormality. Blindness was confirmed by the absence of visual evoked responses. The normal vision group was matched for age (exact matching) and sex. They all had normal visual evoked responses elicited by light flashes. The congenitally blind group received no formal rehabilitation (i.e., standard education using Braille or auditory cues) till the age of sixteen years, when they started to receive vocational training (e.g., weaving).

Design of the Study

Subjects were assessed in a single sitting with two consecutive assessments (RI, R2) of the AEP-MLR, to estimate the reproducibility of the recordings. This was followed by a recording of Visual Evoked Potentials.

Recording of Evoked Potentials

Auditory middle latency evoked potentials were recorded in the 100ms. poststimulus time period, from the vertex referenced to the right earlobe, with the ground electrode on the forehead. The preamplifier band width (Nihon Kohden, Neuropack 8, Japan) was set at 10 to 1500 Hz. Altogether 1500 responses were averaged for each assessment. The rejection level was expressed as a percentage of the full scale range of the analog-to-digital convertor. This level was set at 85%. The number of sweeps was displayed on the monitor. Click stimuli of 40 msec. duration and alternating polarity at the rate of 5 Hz, were delivered binaurally through acoustically shielded earphones (Elga DR-531, Japan). The intensity was kept at 85 dB for all assessments. The threshold of hearing was noted.

Visual evoked potentials were recorded in the 200 msec. time period from Oz, referenced to the right earlobe, with the ground electrode on the forehead. The preamplifier band width was set at 1 to 100Hz and 100 responses were averaged for each period. The method for artifact rejection was the same as for AEP-MLR, as described above. Light flashes were given binocularly, using a LED visual stimulator (Nihon Kohden SLS 3500).

AEP-MLRs Components

Peak amplitudes of short latency wave V, and middle latency Na, Pa and Nb waves were measured from the baseline existing at the beginning of the sweep. Peak latency was measured from the

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time of click delivery. Also the peak amplitudes of AEP-MLR cortical components (i.e., Pa and Nb) recorded from the conventional site (i.e., vertex) were compared with recordings made from the occiput.

The auditory evoked response components were described as follows: wave V was the maximum positive peak between 5 and 8 ms, the Na wave was the maximum negative peak between 10 and 18ms, the maximum positive peak between Na and 35 ms was described as the Pa wave, and the maximum negative peak between 38 and 52ms was described as the Nb wave. These descriptions are similar to other descriptions of AEP components (Erwin and Buchwald, 1986; McPherson, Tures and Starr, 1989; Naveen *et al.,* 1997).

Data Analysis

Comparison of peak latencies between congenitally blind subjects and those with normal vision. The data were analysed using two factor analyses of variance (ANOVA), with Factor A = groups, i.e., congenitally blind *versus* normal vision and Factor B = repeat recordings (R1, R2). The Tukey multiple comparison test was used to detect significant differences between group mean values.

Similar analyses (as mentioned above) were done for the peak amplitudes. The peak amplitudes of the cortically generated Pa and Nb components recorded from Cz and Oz, were compared using two factor analyses of variance. Factor A = groups (congenitally blind, normal sighted) and Factor (B) = sites of recording (Cz, Oz). For these analyses the data of RI and R2 were pooled.

RESULTS

Comparison of peak latencies of congenitally blind and normal sighted subjects showed significant differences between (i) Pa wave (the maximum positive peak between Na and 35ms) and (ii) Nb wave (the maximum negative peak between 38 and 52ms) peak latencies. The latencies of both components were shorter in the congenitally blind compared to subjects with normal vision. However, with the Tukey test for multiple comparisons between mean values the peak latencies of Pa and Nb waves were not significantly different between congenitally blind and normal sighted subjects [$p > .10$, for both comparisons]. With the ANOVA, for Pa wave peak latency [F for Factor A (two groups) = 5.64, since F0.05 (2) 1, 36 = 5.47, hence $p < 0.05$] and for Nb wave, [F for Factor A (two groups) = 4.70, since F.0.05 *(1)* 1, 36 = 4.1 1, hence $p < 0.05$]. The peak latencies of wave V and Na wave did not show a significant difference between groups or repeat recordings and also interaction between factors, *i.e., A x B* ($p > 0.50$). *The* F value for $df = 1.36$ has been derived by linear interpolation from the df = 1,30 and df = 1,40 from the standard table as described (Zar, 1984).

Out of the 10 pairs of subjects studied: (1) in 5 blind subjects both Pa and Nb waves had shorter latencies than those of the matched, sighted subjects, (2) in another 3 blind subjects the Pa wave had a longer latency while Nb wave was shorter than the matched normal sighted, there were also (3) 2 blind subjects who had a shorter Pa wave latency and longer Nb wave latency when compared to the corresponding normal sighted subjects. Examples of 1, 2 and 3 are shown in Figure 1.

There were no significant differences between the peak amplitudes of the AEP-MLR components of congenitally blind and normal sighted groups recorded at Cz (Two factor ANOVA,

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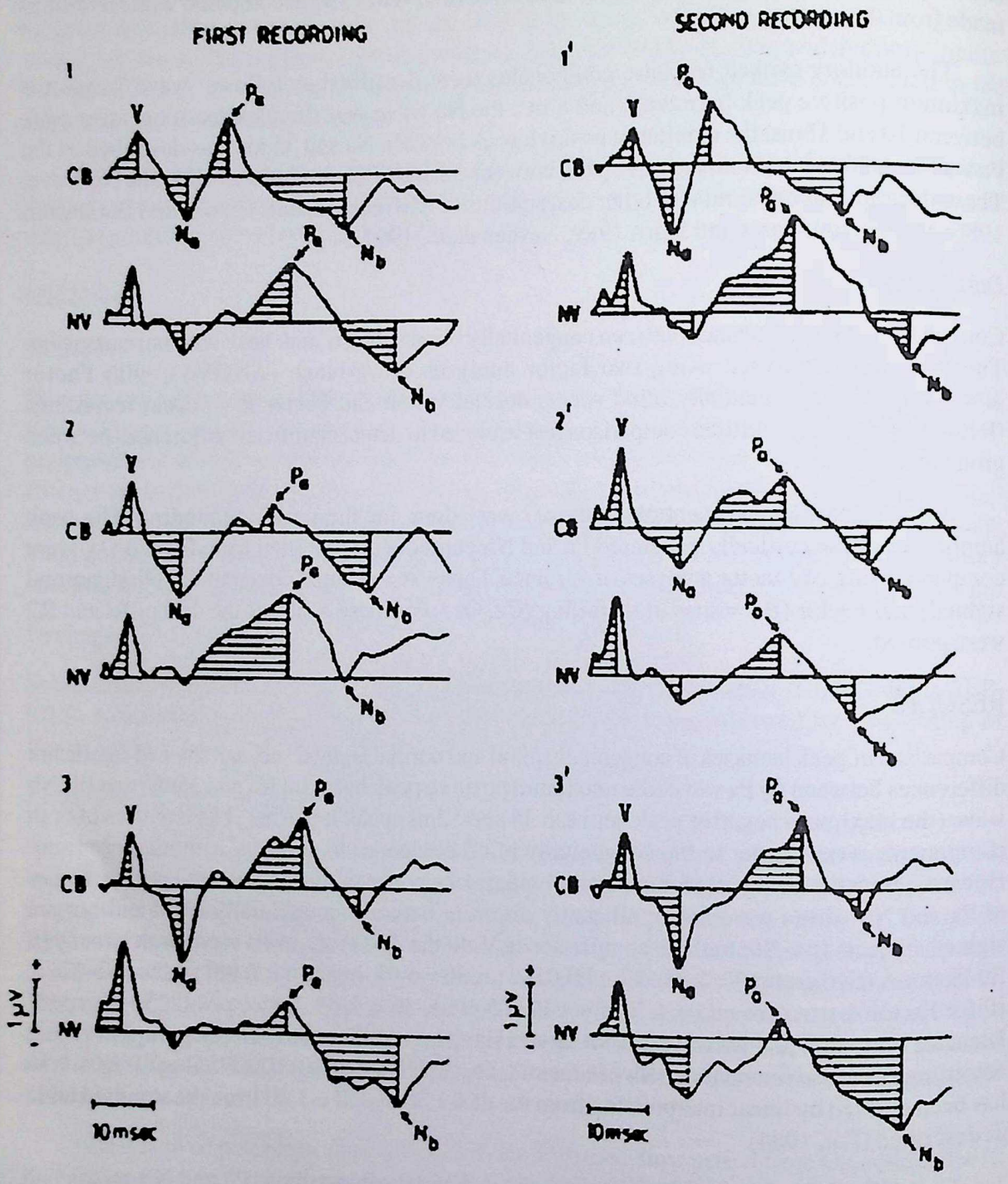

FIGURE 1 : Three examples of AEP-MLRs recorded in congenitally blind (CB) and subjects with normal vision (NV), with two recordings each. The first example (1) shows shorter latencies of Pa and Nb is CB compared to NV for both recordings. In the second example (2), Pa latency is shorter (first recording) or the same (second recording) in CB compared to NV, while Nb latency is longer. The third example shows longer Pa latency and shorter Nb latency in CB compared to NV, for both recordings.

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Factor A = groups, $p > 0.50$ for all comparisons, Factor B = repeat recordings, $p > 0.50$, and interaction between factors (A *x B*), $p > 0.50$.

The peak amplitudes of congenitally blind and normal sighted subjects showed significant differences in the Pa and Nb wave amplitudes recorded at Cz and Oz. For Pa [F for Factor B = sites of recording (Cz, Oz) = 27.2, since FO.00 1 (2) 1, 76 = 13.24, hence $p < 0.00\ 1$], and for Nb wave peak amplitude [*F* for Factor B = 10.6 since FO.002 (2) 1, 76 = 9.8, hence $p < 0.002$]. The Tukey test for multiple comparisons between the peak amplitudes showed a significant difference between the mean value at Cz and at Oz, but not between the groups. The Pa peak amplitude recorded at Cz was significantly higher than that recorded at Oz for both congenitally blind [q = 4.40, since q at probability level 0.025, for *df* = 76, 4 = 4.14, hence $p < 0.025$] and normal sighted subjects [q = 6.04, since q at probability level 0.001, for *df* = 76, 4 = 5.60, hence $p < 0.001$]. With the Tukey multiple comparison test the amplitudes of the Nb wave recorded at Oz and Cz were not significantly different for both congenitally blind and normal sighted subjects ($p > 0.50$).

The group average values of peak amplitudes and latencies of the four components studied, for the congenitally blind and normal sighted subjects are given in Table 1.

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DISCUSSION

In the present study, congenitally blind subjects had significantly shorter peak latencies of two middle latency auditory evoked potential components *viz.*, Pa wave (the maximum positive peak between Na and 35 ms) and Nb wave (the maximum negative peak between 38 and 52 ms was described as the Nb wave) compared to age matched subjects with normal vision. In blind subjects there was no difference between the amplitudes of the cortically generated components (i.e., Pa and Nb) recorded over the vertex (Cz) compared to those recorded from the occipital region (Oz).

Intracerebral recording in man has shown that the neural generator of the Nb wave is relatively localized in the dorsoposterior medial part of the Heschl's gyrs, ***i.e.***. the primary auditory cortex (Liegeois-Chauvel, Musolino, Badier, Marquis and Chauvel, 1994). The pa wave is related to simultaneous activation of both supratemporal auditory cortices (Deiber, Ibanez, Fischer, Perrin and Maugiere, 1988) and changes in Pa wave latency have been regarded as due to modifications in the auditory pathways between the midbrain and cortex (Morlet, Bertrand, Salord, Boulieu, Pernier and Fischer, 1997). Hence in the present study subjects who had no formal rehabilitation with no special programs based on auditory inputs showed similar differences compared to normal

TABLE 1 Peak latencies and peak amplitudes of AEP-MLRs in congenitally blind (CB) and normal vision (NV) groups, n = 10 each.

	Wave V		Na wave		Pa wave		Nb wave	
	CB	NV	CB	NV	CB	NV	CB	NV
Peak Latency (mS)	5.4 ±0.4	5.4 ±0.4	14.4 ±1.4	14.0 ±2.0	27.7** ±0.4	30.1 ±2.8	43.3* ±3.1	45.9 ±3.8
Peak amplitude (uV) at CZ	0.9 ±0.3	0.9 ±0.3	0.8 ±0.4	0.8 ±0.5	0.7 ±0.3	0.8 ±0.5	0.7 ±0.4	0.8 ±0.5
Peak amplitude (uV) at Oz	0.7 ±0.3	0.7 ±0.3	0.7 ±0.4	0.9 ±0.6	0.3 ±0.3	0.2 ±0.5	0.5 ±0.3	0.7 ±0.5

*$P < 0.05$ (one tailed); **$p < 0.05$ (two tailed); two factor ANOVA; CB versus NV

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sighted subjects, as blind subjects who had undergone a formal rehabilitation program (Naveen et al., 1997). In addition there was a shorter latency of the Pa wave, a possible reason is discussed below. The absence of change in the wave V and Na wave suggests that brainstem and diencephalic areas, which are known generators of these waves (Deiber et al., 1988), appear unchanged.

A previous report comparing AEP-MLR components of congenitally blind and normal sighted subjects, showed that blind subjects had a significantly shorter Nb wave peak latency, similar to the results reported in the present study, though in the earlier study there was no significant difference between the peak latencies of the Pa component, between the two groups. Normal sighted subjects of the two groups had exactly the same peak latencies of wave V and Na waves. The Pa wave peak latency of normal sighted subjects of the present study was 1.2ms longer than that of the normal sighted subjects, studied earlier. In contrast, the Nb wave peak latency of normal sighted subjects of the present study was 2.0 ms shorter than that of the normal sighted subjects, studied earlier. These differences were not significant (t-test for unpaired data). It is possible that the longer peak latency of the normal sighted subjects of the present study compared to the normal sighted subjects studied earlier may have contributed to the present result, *viz.*, the significantly shorter Pa peak latency in the blind subjects. There was another difference between the subjects of the earlier study (Naveen *et al.,* 1997) and those of the present study, viz., they belonged to different age groups: for the earlier study, group average age was 14.3 years with a range of 13 to 16 years, whereas subjects of the present study had a group average age of 22.4 years with a range of 18 to 30 years. AEP MLRs were found to he significantly different between subjects of 20-40 years age range and those with an age range of 60-80 years (Woods and Clayworth, 1986). There are no reports available comparing AEP MLRs for the much smaller age difference between the present and earlier studies. However since the differences in peak latency were not significant, any explanation based on the differences may be misleading.

A previous study (Alho, Kujala, Paavilainen, Summala and Naatanen, 1993), had described a larger processing negativity to attended tones at occipital scalp sites in congenitally blind subjects compared to those with normal vision. In the present study smaller amplitudes of Pa and Nb waves of AEP-MLRs were recorded over Oz compared to Cz, in the congenitally blind and normal sighted subjects. Hence there was no evidence of the occipital cortices contributing to cortically generated AEP-MLRs in the blind.

The results hence suggest that irrespective of early rehabilitation programs, there is facilitation of processing of auditory information at the level of the primary auditory cortex. However, the occipital area does not play a role in auditory information processing at primary cortical areas, in the congenitally blind.

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DIFFERENCES BETWEEN CONGENITALLY BLIND AND NORMALLY SIGHTED SUBJECTS IN THE P1 COMPONENT OF MIDDLE LATENCY AUDITORY EVOKED POTENTIALS[1]

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Summary: Auditory evoked potentials (0 to 100 msec. range) were recorded two times for 9 congenitally blind children (age= 14.1 yr. ± 1.4 yr.) and 9 age-matched children with normal vision. The groups peak latency and amplitude of the P1 wave were compared. The peak latency was significantly lower for the congenitally blind than for the normally sighted on a two-factor analysis of variance. Since the P1 wave is thought to correspond to either the ascending, reticular activating system or the primary auditory cortex, these results suggest that information processing at these neural levels may occur more efficiently in the blind.

Congenitally blind subjects were reported by Strelow and Brabyn (1982) to show sensitivity in auditory perception, enabling them to use echoes to perceive spatial positions of objects. This interesting result has a neurophysiological basis. The long latency event related potential waves (NI, P2, and P3) showed shorter latencies and larger amplitudes in early blind humans than those with normal vision (Niemeyer & Starlinger, 1981). The Na and Pa components of middle latency auditory evoked potentials were not significantly different in congenitally blind subjects and those with normal vision (Naveen, Srinivas, Nirmala, Nagendra, & Telles, 1997); however, the Nb component (average peak latency 44.3 msec.) had a significantly shorter latency in congenitally blind persons. This suggested that auditory information processing at the level of the posteromedial part of the primary auditory cortex, the known generator of the Nb wave (Liegeois-Chauvel, Musolino, Badier, Marquis, & Chauvel, 1994) was more efficient in the blind.

The present report presents the analysis of the P1 wave in the congenitally blind and subjects with normal vision described above (Naveen, *et al.* 1997).

METHODS

Subjects

Two groups of 9 subjects each, congenitally blind and with normal vision, were tested. The congenitally blind group (M age 14.1 yr., *SD* 1.4) had a diagnosed peripheral visual deficit from birth and no other abnormality. This was confirmed by an absence of visual evoked responses. The normal vision group (M age 14.0 yr., *SD* = 1.1) had normal visual evoked responses elicited by light flashes.

Design of Study, and Testing Procedure

Subjects were assessed in a single sitting with two consecutive assess ments or recordings (R1, R2).

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Auditory middle latency evoked potentials were recorded in the 100 msec. poststimulus time period, from the vertex referenced to the right earlobe, with the ground electrode on the forehead. The preamplifier band width (Nihon Kohden, Neuropack 8, Japan) was set at 10 to 1500 Hz. Altogether 1500 responses were averaged for each assessment. Click stimuli of 40 μsec., duration and alternating polarity were delivered through acoustically shielded earphones (Elga DR-531, Japan). The intensity was kept at 80 dB for all assessments. The threshold of bearing was noted. Visual evoked potentials were recorded in the 200-μsec. time period, using parameters as described elsewhere (Naveen, *et al,* 1997).

Middle Latency Auditory Evoked Potentials, P1 Component

The peak latency and amplitude of the P1 component were measured from the baseline existing at the beginning of the sweep. The P1 wave is a positive component following the Nb wave (Cacace, Satya-Murti. & Wolpaw, 1990) and occurring between 30 and *100 msec.* (Picton, Champagne, & Kellett, 1992). The components of the P1 wave for congenitally blind subjects and those with normal vision were compared using separate two factor analyses of variance, for the peak latency and the peak amplitude. For this, the first factor was the different groups, i.e., congenitally blind versus normal vision, and the second factor was repeated recordings (R1, R2).

RESULTS AND DISCUSSION

A significant difference in the peak latency of the P1 wave between the congenitally blind (59.85±8.7 msec.) and subjects with normal vision (66.48 ± 6.7 msec.) was noted. These values are the average of 18 values per group, i.e., n=9, with two replications. For the two-factor analysis, for groups $F_{1,32}$=6.24 (F=5.53 at P<.05, two-tailed). The effect size for this ratio was .85. There was no significant difference between replications (ns) and the interaction was not significant (ns). The peak amplitude of the P1 wave was not statistically significantly different between groups congenitally blind (0.54± 0.4μV) and with normal vision (0.70±0.5 μV) or between replications.

The present results indicate that the P1 peak latency is significantly shorter for the congenitally blind compared to the subjects with normal vision. A shorter latency suggests enhanced efficiency of information processing in the underlying neural centers. The P1 wave is thought to correspond to either subcortical structures such as the brainstem ascending reticular activating system (Cacace, *et al.,* 1990) or the dorso-posterolateral part of the Heschl's gyrus, i.e., the primary auditory area (Liegeois-Chauvel, *et al.,* 1994). Hence the present results suggest that these neural centers along the auditory pathway may function more efficiently in the blind, in addition to those more distal reflected by NI, PI, P2 (Niemeyer & Starlinger, 1981) and those more proximal, i.e., Nb wave (Naveen, *et al.,* 1997).

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AUTONOMIC AND RESPIRATORY MEASURES IN CHILDREN WITH IMPAIRED VISION FOLLOWING YOGA AND PHYSICAL ACTIVITY PROGRAMS

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Abstract: We conducted assessments of twenty eight children with impaired vision (VI group), with ages ranging from twelve to seventeen years and in an equal number of age-matched, normal sighted children (NS group). *The* VI *group had significantly higher rates of* breathing, heart rates, and diastolic blood pressure values, compared to the NS group *(Mann- Whitney U test). Twenty four of the* VI *group formed pairs matched for age and* degree of blindness and were randomly assigned to two groups, viz. yoga and physical activity. Both groups spent an hour each day practicing yoga or working in the garden depending on their group. After 3 weeks, the yoga group showed a significant decrease in breath rate (Wilcoxon paired signed ranks test). There was no change after the physical activity program. The results showed that the visually impaired have higher physiological arousal than the normal sighted with a marginal reduction in arousal following yoga.

Key words: *visual impairment, normal sight, autonomic measures, yoga, gardening.*

INTRODUCTION

Young people with impaired vision have significantly higher levels of anxiety related to physical injury, compared to an age-matched group of subjects with normal vision (Ollendick et al., 1985). In addition, one study reported that in comparison to persons who have vision, persons who are blind have a significantly higher heart rate while walking along an unfamiliar route, as well as for five minutes after it (Wycherley and Wicklin, 1970). The authors ascribed this to psychological, rather than physical stress.

The purpose of the life present study was to compare the autonomic and respiratory measures of children with congenital visual impairment with those of a group of age and sex matched children with normal vision. This was the first part of the study. The second part of the present study aimed at comparing the effects of yoga practice with physical activity, in children with visual impairment. The practice of yoga, as based on relaxation (Nagendra, 1989), is able to bring about reduced sympathetic activity alongwith other physiological signs of reduced arousal (Wallace et al., 1971; Joseph et al., 198 1).

METHOD

Subjects

In the first part of the study, we selected twenty eight children (aged between 11 and 17 years, group average age ± SD, 14.2 ± 1.9 years) at random from a special school for the visually impaired (Raman Maharshi Academy for the Blind, Bangalore, India). All of them had congenital visual impairment with an uncorrectable visual acuity of 6/60 or less in the better eye from birth,

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which is the conventional description of blindness (Sheridan, 1969). Blindness was due to peripheral causes, e.g., microphthalmos, congenital cataract or optic atrophy. We selected twenty eight children with normal vision (6/6 without correction) so as to exactly match those with impaired vision with respect to age and sex. We abtained the informed consent of the subjects and their guardians in accordance with the ethical guidelines of the Indian Council of Medical Research, New Delhi, India.

The second part of the study involved twenty four children of the twenty eight assessed in the first part of the study. These twenty four children were selected as they could be matched to form pairs, on the basis of age, sex and degree of visual impairment. The method for grading has been described below, under 'Measurements'. We then randomly assigned subjects of a pair to either of two groups, viz., yoga or physical activity. The group average age ± SD was 14.1 ± 1.9 years (yoga group) and 14.1 ± 2.2 years (physical activity group).

DESIGN OF THE STUDY

In the first part of the study forty children with ages between 11 and 17 years were selected at random from among a total of three hundred and forty children attending a special school for the blind. Out of the forty, twenty eight children with congenital visual impairment were selected for the first part of the study (VI group), as these could be exactly matched with twenty eight children with normal sight (NS group). Matching was based on age and sex. Both groups (visually impaired and normal sighted) were assessed under similar conditions, described in detail below.

The second part of the study was conducted on twenty-four children with impaired vision, out of the twenty eight assessed in the first part of the study. The baseline assessment was carried out in the same way as the first part of the study, one month later. After this the yoga group received training in yoga, while the physical activity group spent time in an outdoor activity (i.e., gardening) for the allotted hour, for five days a week. The yoga instructor spent an equal amount of time with children of both groups. After three weeks both groups were assessed once more. The final assessments were performed by the same persons, under similar conditions as the baseline assessments.

MEASUREMENTS

Recordings for the first part of the study (VI group versus NS group), as well as for the second part (yoga versus physical activity group of visually impaired children), were made in a moderately lit, sound attenuated room. After an initial 15 minute period of supine rest, assessments were made for 10 minutes, also in the supine position and with eyes closed. The blood pressure was recorded from the right arm using a standard sphygmomanometer while the subject was seated. It was not possible to obtain blood pressure records for the second part of the study.

A 10 channel polygraph (Polyrite, Recorders and Medicare, Chandigarh, India) was used to record the electrocardiogram (EKG), respiration and skin resistance level (SRL). EKG was recorded using standard limb lead 1 configuration. Skin resistance was recorded using Ag/AgC1 disc electrodes with electrode gel (Medicon, Madras, India), placed in contact with the volar surfaces of the distal phalanges of the index and middle fingers of the left hand. A low level DC preamplifier was used and a constant current of 10 microamperes was passed between the electrodes. Respiration was recorded using a volumetric pressure transducer. Subjects were asked to stand erect and the transducer was fixed around the trunk, approximately 5 cm below the lower costal margin. The blood pressure was recorded with a sphygrnomanometer.

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The degree of visual impairment was graded for all the children with impaired vision as follows: grade 0, the inability to differentiate between light and dark; grade 1, the ability to differentiate between light and dark; grade 2, the ability to perceive gross movements; and grade 3, ability to count fingers held at a distance of 30 em.

Data extraction and analysis

Data extraction was carried out similarly for both parts of the study. The heart rate (in beats per minute) was obtained by counting the QRS complexes in successive 60 sec epochs, continuously. The breath rate (in cycles per minute) was similarly calculated by counting the breath cycles in 60 sec epochs, continuously. The SRL was sampled at 20 sec intervals. For each subject the average of the values obtained during the 10 minute session was used for analysis.

The data of the V1 group and the NS group were compared using the Mann- Whitney U test. The data of the yoga and physical activity groups obtained at the end of three weeks were compared to the respective baseline data using the Wilcoxon paired signed ranks test.

Yoga training

Yoga was taught by a trained instructor. Individuals with normal vision learn yoga by observing a demonstration while listening to instructions. In the visually impaired detailed verbal instructions were given to compensate. In addition, the instructor spent time with each subject correcting their practice (e.g. repositioning their limbs) with verbal instructions. Special emphasis was given to relaxing between practices and being aware of body sensations. Practices included simple yoga postures and yoga breathing exercises (50 minutes), followed by guided relaxation (10 minutes). Throughout the practices the emphasis was on awareness (of physical and other sensations) and relaxation.

Physical activity

The physical activity group did not learn yoga. During the allotted hour they spent time in the garden, doing a comparable amount of physical activity as the yoga group, such as bending forwards and stretching upwards. The yoga instructor spent time with these children every day and was equally familiar with them as with the yoga group.

RESULTS

Part one of the study

In a comparison with the normal sighted, subjects with impaired vision had significantly higher breath rates, diastolic blood pressure values, and heart rates. For breath rate. Z μ 2.71 and Z.01 (2) a = 2.57, hence P< .01; for diastolic blood pressure: W = 3.79 and Z.001 (2) μ = 3.20, hence P<. 001, and for heart rates: Z μ = 1.66 and Z.05 (1) et = 1.64, hence P<.05. The group mean values ± SD are presented in Table 1.

Part two of the study

There was a significant decrease in the breath rate of the yoga group, at the end of three weeks using the Wilcoxon paired signed ranks test (T=10, T.05(2) 12 = 13, hence P<.05). The group mean values ± SD are presented in Table II.

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DISCUSSION

The present study was carried out in two parts. The first part of the present study showed that children with impaired vision had higher diastolic blood pressure values, heart and breath rates, compared with normal sighted children of the same age. When the children with impaired vision were randomly assigned to yoga and physical activity (i.e., gardening groups), three weeks of yoga practice caused a reduction in the rate of breathing.

An increase in breath rate has been correlated With experimentally evoked fear and anxiety (Ax, 1953), as well as before situations such as parachute jumping (Fenz and Jones, 1972). The nature of waveforms recorded in a standard spirogram using a strain gauge transducer showed that there were different patterns as the immediate response to six selected emotions, including fear and anxiety (Bloch et *al.*, 1991). These two emotions were found to be particularly likely to cause irregularity of breathing, with frequent periods of breath holding, whereas anger and sadness were found to produce regularly recurring abnormal patterns. Visual assessment of the records of the children with impaired vision and those with normal sight showed that the former had irregular breath cycles with frequent periods of breath holding. This may be due to higher levels of fear and anxiety in the visually impaired. This is in keeping with the report which described higher levels of fear (particularly related to physical injury) in the visually impaired (Ollendick *et al.*, 1985). These subjects were possibly apprehensive as they were not familiar with the laboratory. In connection with this it may be noted that the subjects with normal sight were also visiting the laboratory for the first time. Also, equal efforts were made to reduce the apprehension of both groups by explaining the procedure in detail and answering their questions.

A low resting heart rate is an indicator of routine physical activity (Williams and Sperryn, 1962). Children with impaired vision were found to have poor physiological adjustment to exercise compared to their normal sighted counterparts (Hopkins et *al.*, 1987). This was ascribed to an overall lower level of physical activity in these children. This explanation fiat a higher resting heart rate found in the children with impaired vision in the present study, could also apply to the higher (though not abnormally so) diastolic blood pressure values in the blind children.

In the second part of the study, the effect of two programs (yoga and increased physical activity during gardening) was assessed, using the same parameters as for the first part of the study. Previous reports have shown that yoga reduces psychophysiological signs of arousal (Wallace *et al.*, 1971). The present results have shown that the yoga group showed a significant reduction in respiratory rate after three weeks of practice, while the group who were given gardening showed no change. The effects of yoga on the rate of respiration have been described in the previous literature. The practice of yoga reduces the breath rate, both as an immediate effect (Wallace et *al.*, 197 1) and over a three month period (Joseph *et al.*, 1981).

The present study showed that the practicing yoga for three weeks reduced the breath rate in children with impaired vision. Other known effects of yoga practice (e.g. a reduction in heart rate or an increase in skin resistance) were not observed. In fact, there was a non significant decrease in skin resistance following yoga, which could not be explained. It is possible that the duration of practice required to bring about a change in these parameters in the visually impaired is longer than in other individuals, as the latter have higher heart and breath rates and diastolic blood pressure values to begin with. These higher values may have been contributed to by the unfamiliar laboratory setting.

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The practice of yoga modified the irregularity of breathing which was observed in the baseline assessment. These results are similar to the effects of yoga observed in community home children (Telles et al., 1997). As described earlier, an increase in breath rate was found to occur in response to fear, anxiety and other psychological stressors (Ax, 1953).

Hence the present results suggest that the visually impaired have higher levels of cardiac sympathetic activation and faster breathing than the normal sighted. A comparison of three weeks of yoga practice with a physical activity program showed that after the practice of yoga, the rate and irregularity of respiration was reduced. There were no other changes. Yoga techniques involve increased physical activity, with an emphasis on relaxation and awareness. This type of program appears to be useful to reduce irregularities in breathing which may be associated with anxiety, in the blind.

TABLE I : Autonomic measures in visually impaired (VI) and normal sighted (NS) children. Values are group mean ± SD

	VI (N=28)	NS (N=28)
Heart rate (beats per minute)	88.8 14.5	81.6 11.3
Breath rate (cycles per minute)	22.8 5.4	19.2 3.2
Skin resistance (K ohms)	176.7 ±153.3	136.9 ±100.9
Systolic BP (mm Hg)	113.0 ± 11.5	110.7 9.5
Diastolic BP (mm Hg)	76.1 ±6.4***	66.5 8.9

**P< 0.05 (1), * * P < 0.01 (2), *** P < 0.001 (2) Mann - Whitney U test, "VI" versus "NS".*
N = Number of subjects

TABLE II : (Yoga, physical activity) of children with impaired vision before and after the three week programs. Values are group mean ±SD

	Yoga training N = 12		Physical activity N = 12	
	Before	After	Before	After
HR (beats 1 minute)	89.0 ±19.4	82.8 ±13.4	84.7 ±8.1	84.9 ±12.3
RR (cycles 1 minute)	21.4 ±6.3	17.5* ±6.9	22.9 ±5.1	21.5 ±4.8
SR (Kilo ohms)	130.8 ±124.8	67.6 ±74.0	128.7 ±1.3.0	136.3 ±172.6

**p < 0.05 (2), Wilcoxone paired signed ranks test after versus before.*
N = number of subjects

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YOGA FOR THE REHABILITATION OF SOCIALLY DISADVANTAGED AND VISUALLY IMPAIRED SUBJECT

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Abstract: This study was designed (i) to compare autonomic parameters in two categories of subjects (age range 12 to 17 years), viz. community home girls (CH, n=20) who were admitted due to problems in adjusting in society, and congenitally blind subjects (CB, n=28) with appropriate age-matched, control groups i.e. children staying at home and those with normal vision, respectively, (ii) to compare the effect of yoga with games (n= 14 each) in the CH group and the effects of yoga with gardening (n=12 each) in the CB group. Polygraphic recordings were made of respiration, EKG, and skin resistance. The community home group were randomly assigned to yoga and games groups and followed up after six months, while for the congenitally blind group subjects were randomly assigned to yoga and physical activity group with a follow up after three weeks. In the first comparison community home girls had significantly faster, irregular breathing (indicative of anxiety) and lower skill resistance, while blind children had faster, irregular breathing and higher heart rates and diastolic blood pressure values. In the second comparison the yoga groups of both categories of subjects showed a decrease in breath rate, which became more rhythmic. Hence a yoga program including relaxation and awareness is useful in the rehabilitation of these subjects.

Key words: *Community home; congenitally blind; autonomic measures; Yoga.*

INTRODUCTION

Mental arousal may be correlated with diverse factors related to family or environment, as well as the status of one's physical and mental health. For example children in a community home in Finland were described as physically normally developed but were socially and emotionally traumatized (Ahvenainen, Lindholm, & Nikkanen, 1984). A report on physiological measures showed that the resting electrical activity of selected facial and back muscles was significantly higher in community home boys than in a control group of the same age in an ordinary school (Rauhala, Alho, Hanninen, & Helin, 1990). Another group of subjects who were reported to have significantly greater levels of anxiety than usual is subjects with impaired vision. This greater anxiety was specially related to physical threat (Ollendick, Matson. & Helsel,1985). In a blind-sighted comparison, blind persons were found to have a significantly higher heart rate while walking along an unfamiliar route as well as for five minutes after it (Wycherley & Nicklin, 1970). This was ascribed to psychological, rather than physical stress.

The practice of yoga is known to reduce autonomic arousal (Wallace, Benson, & Wilson, 1971; Joseph, Sridharan, Patil, Kumaria, Selvamurthy, Joseph, & Nayar, 1981). Increased physical activity has been shown to reduce autonomic reactivity to mental stressors (Steptoe, Kearsley, & Walters).

The present report compares the autonomic arousal of two groups of subjects, i.e. socially disadvantaged community home girls (Telles, Narendran, Raghuraj, Nagarathna, & Nagendra

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1997) and physically disadvantaged blind children. Both groups were compared to their respective control groups. The second part of the report describes and compares the use of yoga with games or physical activity such as gardening.

2. METHODS

Subjects and design of the study

In part 1 there were 20 community home girls with ages ranging from 12 to 17 years. They all had a history of difficulty in adjusting at home or in society. A comparison was made with 20 age-matched girls (± 6.0 months) who were attending a regular school and staying at home. Also twenty eight congenitally blind children of the same age-range were compared with all equal number of age and sex matched subjects with normal vision. In part 228 community home girls were divided into pairs matched for age and duration of stay in the community home. Subjects of a pair were randomly assigned to yoga and games. The follow up was carried out after 6 months. Also, 24 blind children were divided into pairs matched for age, sex, and degree of blindness. Subjects of a pair were randomly assigned to yoga and games groups. The follow up was carried out after 21 days.

Measurements

Measurements for part 1 were made under identical conditions. A moderately lit, sound attenuated cabin was used for recording. After 15 minutes of rest assessments were made for 10 minutes while subjects were seated at ease.

A 10-channel polygraph (Polyrite Recorders and Medicare, Chandigarh, India) was used to record the electrocardiogram (EKG), respiration, and the skin resistance. The EKG was recorded using standard limb lead 1 configuration. Skin resistance was recorded using silver chloride disc electrodes filled with electrode paste, and placed in contact with the volar surfaces of the distal phalanges of the index and middle fingers of the left hand. A constant current of 10 microamperes was passed between the electrodes. Respiration was recorded using a volumetric pressure transducer. Subjects were asked to stand erect and transducer was fixed around the trunk, approximately 5 cm below the lower costal margin. The blood pressure was recorded with a sphygmomanometer.

Yoga, games, and physical activity programs

Yoga techniques included Simple yogasanas, postures which are maintained for as long as possible (50 minutes) and guided relaxation in shavasan (10 minutes). The games session included jogging in place. Rapid bending forward and backwards, twisting, and bending sideways (40 minutes) as well as games such as relay races in which all the girls had to take an active part for 20 minutes. The physical activity program consisted of working in the garden, with comparable physical exercise as that of the yoga program, involving a similar amount of bending or stretching.

Data extraction and analysis

Polygraphic data were scored blind as follows. The heart rate in beats per minute was obtained by counting the number of QRS complexes in successive 60-sec epochs continuously. The skin resistance (in kiloohms) was sampled at 20-sec intervals continuously. The breath rate in breath cycles per minute was obtained by counting the breath cycles in 60-sec epochs continuously. For each subject the average of values obtained during the 10-min recording session were analyzed. In Part I of the study comparisons were made using the Mann Whitney U test. In part II comparisons between yoga and the corresponding group were made using the Wilcoxon signed ranks test.

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3. RESULTS

Part I (see Table 1) : The community home group had significantly faster breath rates and lower skin resistance values than the regular school group. The group with impaired vision had significantly higher heart rates, breath rates and higher diastolic blood pressure values than the group with normal vision.

Part II (see Table 2): Both the community home groups (yoga, games) showed significant reductions in heart rate through the magnitude of change was similar to non significant decrease in breath rate following 6 months of the programs. The yoga group alone showed a decrease in breath rate though the magnitude of change was similar to the non- significant decrease in breath rate seen in the games group. In the visually impaired subjects the yoga group showed a significant decrease in breath rate.

TABLE 1: Percentage change in autonomic parameters in community home and visually impaired subjects with reference to their respective control groups

Groups	Heart rate	Breath rate	Skin resistance	Systolic BP	Diastolic BP
Community home (n =20)	+ 2.4	+ 22.9*	- 40.6*	–	–
Visually impaired (n = 28)	+ 8.8	+ 18.8*	+ 29.0	+ 2.0	+ 14.4

+, - Indicates increase, decrease, respectively. ** indicates significant difference compared to the control*

TABLE II : Percentage changes in autonomic parameter in both groups of community home and visually impaired subjects.

Groups	Heart rate	Breath rate	Skin resistance
Community home			
Yoga (n =14)	-17.3*	-5.3*	-15.7*
Games (n = 14)	-13.8*	-5.8*	-20.0
Visually impaired			
Yoga (n = 12)	-7.0	18.2*	-48.3
Activity (n = 12)	-0.2	-6.1	+5.9

+, - indicates increase, decrease respectively and end of the programs compared ** indicates a significatn difference when data from at the start*

DISCUSSION

Part 1 of the study showed that community home girls had significantly higher heart rates and lower skin resistance values than girls of the same age who were living at home. Also the visually impaired subjects had significantly higher heart rates, breath rates and diastolic blood pressure values compared to children with normal sight. Part 2 of the study showed that within both categories of subjects (community home, visually impaired) the yoga groups showed significant reductions in breath rates. In the community home group both yoga and games group showed decreases in heart rates. It was interesting to note that the changes in skin resistance occurred in

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opposite directions for the yoga and non-yoga groups of both categories of subjects. The community home girls yoga group showed an increase in skin resistance, while the games group showed a decrease in skin resistance. The reverse was true for the visually impaired subjects.

Both the community home and visually impaired subjects showed signs of physiological arousal. These results were similar to previous reports on community home boys (Rauhala et al.. 1990) and the visually impaired (Wycherley & Nicklin. 1970). The most obvious difference between the groups was that the community home group had a lower skin resistance than normal and the visually impaired had a higher skin resistance than normal. Both categories of subjects reduced their breath rates following yoga. Visual inspection of the records of both categories of subjects showed that both the Community Home and visually impaired subjects showed more irregular breath patterns than the corresponding control subjects. Fear and anxiety were likely bases for irregular breathing i.e., very rapid and jerky (Ax. 1953; Bloch, Lemuignan, & Aguilera-T, 1991). The fear and anxiety of the community home group were believed to be related to social insecurity, whereas that of the visually impaired subjects was attributed to fear of physical injury in the unfamiliar laboratory setting (Ollendick et al., 1985). Also there was a difference in skin resistance values the community home yoga group showed an increase, whereas the visually impaired yoga group showed a decrease in skin resistance values. This was specially interesting as the community home group had a lower skin resistance to begin with, while that of the visually impaired was higher than the control initially. Hence it appeared that the practice of yoga not only reduced arousal but also served to normalize other functions in both categories of subjects.

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MUSCLE POWER DEXTERITY SKILL AND VISUAL PERCEPTION IN COMMUNITY HOME GIRLS TRAINED IN YOGA OR SPORTS AND IN REGULAR SCHOOL GIRLS

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Abstract : The present study was conducted to compare critical flicker fusion frequency (CFF), degree of optical illusion ("di"), dexterity scores, and grip strength in three groups of subjects, viz community home girls who had learned yoga for 6 months (CHY), age-matched community home girls who had physical activity training for 6 months (CHP), and girls who were attending a regular school (SCH). There were equal numbers in each group for each of the 4 assessment (range 11 to 30 subjects) and age range was 12 to 16 years. The CHP group had significantly lower CFF and "di" was significantly higher (one factor ANOVA, t test for unpaired data) in the CHP group, both compared to CHY and SCH groups. Right hand grip strength was also significantly less in the CHP group compared to SCH. The results were explained by previous reports of high levels of anxiety and aggression in community-home groups, which is known to influence the four parameters described here. The better performance of the CHY group compared to CHP, suggested that yoga practice has a beneficial effect in these subjects.

Key words : *community home; physical activity; yoga; motor strength and skill; visual perception.*

INTRODUCTION

Children who are unable to adjust at home, at school or in society are admitted to community homes. Previous studies have established that these children were socially and emotionally traumatized, although physically normal (1). They also reported anxiety and fears and were more aggressive. A report on physiological measures showed that the resting electrical activity in selected facial and back muscles (EMG) was significantly higher in community home boys compared to boys of the same age in an ordinary school (2). This increase was attributed to a high level of stress, as the EMG tone was found to decrease after the subjects underwent a program which included both physical training and relaxation. A subsequent report compared the effects of increased physical activity with those of relaxation with awareness through yoga in community home girls (3). To begin with, community home girls had higher respiratory rates and lower skin resistance values compared to an age matched group of girls who were staying at home and attending a regular school. At the end of six months the community-home yoga group had a greater decrease in heart rate, respiratory rate and an increase in skin resistance, compared to a matched, community-home physical activity group. These changes also suggested that yoga decreased physiological signs of stress.

The present study was conducted to compare the motor and sensory (visual) performance of community home girls who had learnt yoga with that of community- home girls trained in physical activity and of girls staying at home. Four tests were used, viz. (i) hand grip strength as an indicator of muscle power, (ii) degree of optical illusion using Muller-Lyer lines as a measure of accuracy of visual perception, (iii) critical flicker fusion frequency also to assess visual

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perception, and (iv) tweezer dexterity to assess motor skills. The community-home girls belonged to two categories. Prior to the assessments one category had training in yoga for six months, while the other category had a program of increased physical activity for the same duration. This study also compared both categories of community-home girls with age matched girls from an ordinary school.

METHODS

Subjects: The subjects were 80 girls from a state community-home. They were between 12 and 16 years of age and had been admitted because of difficulty in adjusting at home, at school, or in society. Fifteen were from broken homes, with one or both parents dead or separated. Their duration of stay in the home ranged from 6 to 36 months. The 80 girls were divided into pairs matched for age and duration of stay in the home. It was possible to form 30 such pairs. Subjects of a pair were randomly assigned to either one of two groups viz., yoga (CHY) and physical activity (CHP). A third group of girls who were staying at home and attending an ordinary school (SCH), were matched as far as possible for age (± 6 months to 2 years) with the two groups from the community-home. All three groups (CHP, CHY, SCH) were assessed similarly. However, it was not possible to collect data on the degree of optical illusion in the control (SCH) subjects. Hence data obtained on adults living at home were used as control values. For each of the tests the number of subjects was different (Table 1).

Design of the study: All three groups i.e., community-home group who had practised yoga for six months (CHY), community-home group who had training in physical activity for the same duration (CHP), and girls who were staying at home and attending a normal school (SCH), (or as described above, for the degree of illusion assessment, normal adults), were assessed for each of the four tests (detailed below) on four separate occasions.

Parameters: All subjects were assessed in the four parameters described below.

(i) Hand grip strength was measured using a hand grip dynamometer. Subjects were asked to extend their arms horizontally parallel to the ground, without support and grip the dynamometer using maximum strength. Three trials were given for each hand, alternately, with 10 Sec gap between trials, the highest among the three values was used for analysis

Table 1. Number of subjects (n) and mean age ± SD of each group for all the four assessments.

Assessment	n	CHY		CHP		SCH	
		mean age	SD	mean age	SD	mean age	SD
Grip strength	11	13.9	1.3	13.6	1.4	13.8	1.1
Tweezer dexterity	15	13.6	2.9	13.8	1.8	11.4	1.8
Critical flicker fusion	30	13.9	1.9	12.9	2.6	13.6	1.5
Optical illusion	30	13.9	1.9	12.9	2.6	28.9*	6.3

** = adult subjects*

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(ii) Tweezer dexterity was measured using the O'Connor tweezer dexterity apparatus, which consists of a metal plate which has 100 holes (2.0 mm in diameter and 20.0 mm deep) spaced 15.0 mm apart. The subject was instructed to pick up metal pins (1.5 mm in diameter and 25.0 mm in length) with a tweezer and place them in the holes as quickly as possible. The number of pins placed within 4 min was noted.

(iii) Critical flicker fusion frequency was measured using an electronic flicker fusion apparatus, with flicker rate ranging from 12 to 95 Hz. The flickering stimulus was a red light, 6 mm in diameter with intensity of 50 mcd, surrounded by a white surface with illumination of 150 lux. Subjects were seated 50 cm away from the apparatus, with their gaze on level with it. All subjects were assessed in ten ascending trials, which began with minimum frequency (12 Hz for the apparatus used). The frequency was increased at the rate of 0.5 Hz per step, till the subjects felt that the stimulus was no longer flickering, i.e. it was "fused" (fusion threshold).

(iv) Optical illusion was measured using Muller-Lyer lines. Subjects were assessed in two types of trials, i.e., " in" and "out" using "the method of limits" with the experimenter varying the lengths of the lines. The Muller-Lyer lines, though of equal length, appear unequal due to two different types of arrows drawn at the ends of the line. In the apparatus used, for the present study, the line on the left had close-ended arrows at either end, making it appear shorter. The length was fixed (in mm). In contrast the length of the line on the right could be varied. This line had open-ended arrows at either end which made it appear longer. The experimenter manipulated the length of the line according to the subjects specifications. The exact position at which the subject perceived the two lines to be of equal length was noted, i.e. subjective reading - "sr". The difference between the reading at which the lines were actually equal and the " sr " gave the degree of illusion, "di". Each subject of three groups was assessed in two types of trials (ten each, given alternately). For "in" trials the examiner adjusted the length of the adjustable line, 1 mm at a time, changing the length from maximum (200 mm) till the subjects perceived the length to be equal to that of the fixed line (actual length = 160 mm). For "out" trial the procedure was reverse, the adjustable line was kept to minimum length and the length was gradually increased till the subjects perceived the length to equal that of the fixed line. In both cases the difference (in mm) between the actual length of the fixed line and the perceived length was noted as the degree of illusion, "di".

For all 4 tests the apparatuses were from Anand Agencies, Pune, India

Yoga training

Staff members of the community-home who were previously trained in yoga, were involved in teaching and supervision. A trained yoga teacher visited the class every fortnight to cheek the practice. Yoga techniques included: (i) simple yogasanas for 50 minutes (these are postures which are maintained for as long as possible, while relaxed), and (ii) a 10 minute period of relaxation in shavasan (corpse posture). Throughout both practices the emphasis was on relaxation and awareness of physical and other sensations.

Physical activity

Physical activity training included stationary jogging, rapid bending forwards and backwards, twisting and bending sidewards. These practices were for 40 minutes. The session also included 20 minutes of playing games such as relay races in which all the girle had to participate actively.

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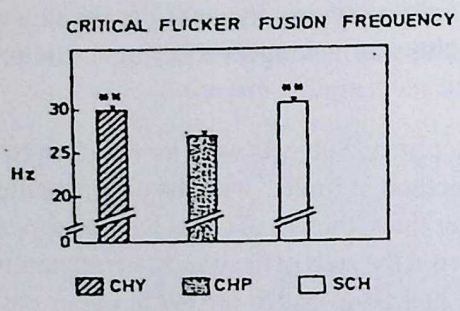
RESULTS

The data for all four assessments (grip strength, tweezer dexterity, critical flicker fusion frequency, and degree of optical illusion (Muller-Lyer lines)) of the three groups were compared for significant differences using separate single-factor analysis of variance (ANOVA). The group average values were tested for significant differences using the 't' test for unpaired data comparing two groups at a time. The single factor ANOVA showed a significant difference between the critical flicker fusion frequency values of the 3 groups, [F = 18.36, F.001 (2) 2, 87 = 8.30, hence P<. 001] and for the degree of optical illusion using the Muller-Lyer lines during "in trials" [F = 18.99, F.001 (2) 2, 87 = 8.36, hence P<. 001]



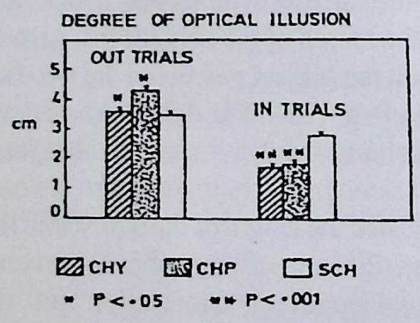
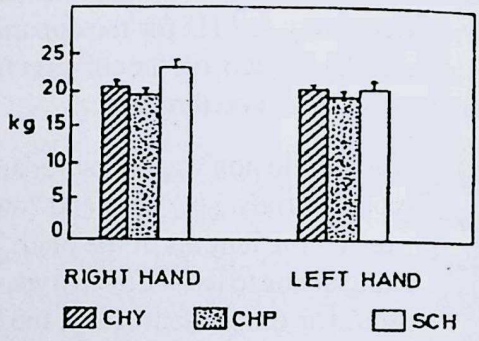


*Fig.1: Critical flicker fusion frequency and degree of optical illusion in community home yoga group (CHY) and community home physical training group (CHP) compare3d to ordinary school group (SCH). *P<.05, **P<.001, 't' test for unpaired data.*



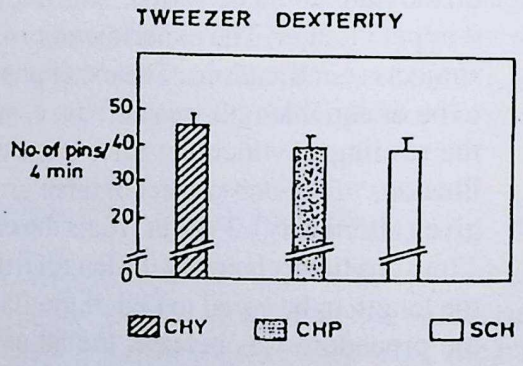


Fig.2: Hand grip strength and tweezer dexterity scores in community home yoga group (CHY) and community home physical training group(CHP)compared to ordinary xchool group (SCH)

(Fig.1) There was no significant difference between the three groups for degree of optical illusions for "out trials", hand grip strength scores obtained for either hand or for the tweezer dexterity scores (P<0.1 in both cases) (Fig 2).

The 't' test for unpaired data showed the following significant difference (i) Critical flicker fusion frequency was significantly lower in the CHP group, compared to SCH group (t = 5.72, P<0.01) and 'compared to CHY group (t =5.72, P<0.01). (ii) Degree of optical illusion for "out trials" i.e. the "di' was significantly higher (marginal difference) in the CHP group compared to SCH (t = 1.92, P<.05). (iii) Grip strength was significantly lower in 'CHP group compared to SCH group for the right hand (t = 2.00, P<. 05, one tailed).

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DISCUSSION

The present study showed that community home girls who had received physical training (CHP group) have significantly lower critical flicker fusion frequency (CFF), higher degree of optical illusion ("di") for "out trials", but not for "in trials", and lower right hand grip strength compared to girls of the same age who were staying at home and attending an ordinary school (SCH group). The community home girls who had received six months of training in yoga (CHY group) performed better i.e. higher CFF, 'lower "di" an "out trials" and marginally greater hand grip strength, than the CHP group, and were not significantly different from the SCH group. The data of the community home groups before they had learned yoga/physical training were not available. Hence the base line performance of these groups of subjects was not known. The hand grip is believed to be influenced by the availability of energy and oxidation requirement (12).

The CFF has been correlated with factors such as physical stresses e. g. nutritional deficiency, fatigue during physical work, or sleep deprivation (4) as we11 as emotional stress (5). Greater stress levels have been correlated with lower CFF values. The "di" has also been correlated with cognitive factors such as the experience, hypotheses, and strategies of judgement (6). In the present study, the lower CFF values and higher "di" in the "physical activity" community home group could possibly be related to the higher stress levels, which earlier reports indicated that these subjects were specially likely to have (1, 2, 3). The CHY group did not have significantly different values for both CFF and "di" compared to SCH group. This could be related to the fact that the practice of yoga for short periods (10 to 30 days) has been shown to increase the CFF (7) and reduce optical illusion (8). The hand grip strength and tweezer dexterity scores did not differ significantly between the three groups using a single factor ANOVA. However, the 't' test for unpaired data showed a significantly lower right hand grip strength in the CHP group compared to SCH group. The absence of major differences between the groups for these two parameters could be explained in either of two ways, viz (i) the factors responsible for lower visual sensitivity (low CFF, high "di") in the CHP group of community home girls may not be applicable to grip strength/tweezer dexterity; (ii) alternatively, both yoga and increased physical activity may have been effective in the reducing adverse factors in the CHP and CHY groups with regard to grip strength or dexterity scores while there were still differences in CFF and "di". The grip strength and dexterity scores of the three groups hence appeared the same. The former explanation is contradicted by a very early report in the literature which describes poor performance in "asylum" children when hand grip strength and manual dexterity were tested (9). The latter explanation may be more acceptable. There are reports that the practice of yoga increases grip strength (10) and improves dexterity. A previous study has shown a comparable effect of yoga and physical training on grip strength and specific tanks requiring motor skills (11). This also may explain why no differences were observed between the two groups of community home girls for these two parameters, even though the CHP group had lower right hand grip strength than the SCH group. The physiological basis for the perception of optical illusion and of a flickering light stimulus are similar. In both cases changes at retinal, cortical and cognitive judgemental levels influence visual perception. However, in the case of flicker fusion, the peripheral visual pathway is specially important, and may be related to the frequency at which the optic tract discharges and to the discharge rate of "on-off" ganglion cells in response to an intermittent stimulus. Also in the perception of an optical illusion cognitive-judgemental factor are stressed (6).

The hand grip is believed to be influenced by the availability of energy and oxidation requirement (12). These factors may also be expected to influence the performance in a repetitive task requiring fine motor skills (i.e. the, dexterity test).

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Hence the present study suggests that the reported higher stress levels in community home inmates reduced sensory perception by causing change at peripheral and central levels. To some extent yoga practice modifies this effect. Similarly muscle power (but not fine motor skill), was less in the community home group. Yoga practice also appeared to improve hand grip strength, perhaps by reducing the energy requirement. However, additional information on the baseline status of the community home group, prior to either training (which was not available in the present study) would be required to draw more definitive conclusions.

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COMPARISON OF CHANGES IN AUTONOMIC AND RESPIRATORY PARAMETERS OF GIRLS AFTER YOGA AND GAMES AT A COMMUNITY HOME

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Summary : The heart rate, breathing rate, and skin resistance were recorded for 20 community home girls (Home group) and for 20 age-matched girls from a regular school (School group). The former group had a significantly higher rate of breathing and a more irregular breath pattern, known to correlate with high fear and anxiety, than the School group. Skin resistance was significantly lower in the School group, which may suggest greater arousal. 28 girls of the Home group formed 14 pairs, matched for age and duration of stay in the home. Subjects of a pair were randomly assigned to either yoga or games groups. For the former, emphasis was on relaxation and awareness, whereas for the latter increasing physical activity was emphasized. At the end of an hour daily for six months both groups showed a significant decrease in the resting heart rate relative to initial values (Wilcoxon paired-sample test), and the yoga group showed a significant decrease in breath rate, which appeared more regular but no significant increase in the skin resistance. These results suggest that a yoga program which includes relaxation, awareness, and graded physical activity is a useful addition to the routine of community home children.

From Finland, reports are available on the psychophysiological status of children with problems at home, in school, or in society, who are admitted to community homes, governed by special legislation (Ahvenainen, Lindholm, & Nikkanen, 1984). These children were described as physically normally developed but were socially and emotionally traumatized. They were also reported to describe more anxiety and fears than is usual and to be extra aggressive. A report on physiological measures showed that the resting electrical activity of selected facial and back muscles (EMG) was significantly higher in Community Home boys than in a Control group of the same age in an ordinary school (Rauhala, Alho, Hanninen, & Helin, 1990). This was considered likely increased by stress. After four months of relaxation training combined with increased physical activity, the EMG measures of the Community Home group decreased compared to their baseline values as well as compared to the initial values of the Control group.

The present study was conducted with girls in a community home in South India, who (like the children in Finland described above) were admitted due to problems in adjusting at home or in society. The aim was to examine whether there would be differences in standard psychophysiological measures (heart rate, skin resistance, and breath rate and pattern) of these girls compared to girls of the same age who were staying at home and attending a regular school. This was the first part of the study.

In the second part of the study, a comparison was made of the effects of two interventions (yoga and games) on the same measures recorded for Community Home girls. The routine of the community home included education, work, and psychotherapy. Yoga or games were introduced

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for the first time. Yoga emphasizes relaxation with awareness, whereas playing games was intended to increase the physical activity. The reason for selecting these interventions can be understood from previous reports. Increased physical activity has been shown to reduce autonomic reactivity to mental stressors (Steptoe, Kearsley, & Walters, 1993). Also, the practice of yoga reduces autonomic arousal (Wallace, Benson, & Wilson, 1971; Joseph, Sridharan, Patil, Kumaria, Selvamurthy, Joseph, & Nayar, 1981). The study allowed comparison of the effects of relaxation with those of increased physical activity, which had been combined in the previous study of children in a community home (Rauhala, et al., 1990)

METHOD

Subjects

In Part one, 40 girls between 12 and 16 years of age were selected at random from a total of 120 girls in a community home. All had a history of difficulty in adjusting at home or in society. Fifteen were from broken homes (one or both parents were dead or their parents were separated). For comparison, another 40 girls of the same age group were selected at random from students who were attending a regular school and living at home. Both groups were from similar socioeconomic backgrounds. A routine medical examination verified that the girls had normal health, and none was receiving medication. For both groups the informed consent of the subjects and their guardians was obtained.

The second part was carried out on 28 girls of the 40 from the community home. They were randomly assigned to either the yoga or the games group. The group's average age ± *SD* was 15.1 ± 0.6 yr. (games group) and 14.9 ± 0.6 yr. (yoga group). The duration for which they had lived in the home ranged from 6 to 36 mo. (average for the games group was 12.8 mo. and for the yoga group 12.0 mo.).

Design of the Study

In Part one 40 girls aged between 12 and 16 yrs., were selected at random from the residents of a community home. Forty girls from a regular school who were of the same age group and socioeconomic status were selected for comparison. The two groups were matched for age (±6 mo). Of the 80 girls 20 age-matched pairs could be formed for comparison. Their data were analyzed. Both groups were assessed polygraphically under similar conditions.

In the second part, the community home girls alone were assessed. Out of the 40, 28 girls were matched for age (±6 mo.) and duration of stay in the community home (±2 mo.). Subjects of a pair were then assigned to a random order of the two groups, viz., games or yoga. The baseline assessments of these groups were made in a similar manner before the programs commenced. After this the Yoga group received training in yoga, while the Games group played games for an hour, at the same time of the day, five days a week. The programs were not part of the earlier routine. The staff members of the home supervised the programs. Also, staff were asked to alternate between supervising yoga and games on different days. After six months of practice, both groups were assessed once more, under conditions like those of the baseline assessment. The subjects were also asked to give a report of their experience of the program in which they had participated.

Yoga training

Staff members of the community home who were first trained in yoga were involved in teaching and supervising the subjects. A trained yoga teacher visited the class every fortnight to check the

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practice. Yoga techniques included simple *yogasanas,* postures which are maintained for as long as possible while relaxed for, 50 minutes. As subjects had more experience in yogasanas the time for which the posture was maintained was gradually increased. Also, brief (10-min.) relaxation in *shavasan* (corpse posture) was included. Throughout both practices, the emphasis was on relaxation and awareness of physical and other sensations.

Games

The session included jogging in place, rapid bending forwards and backwards, twisting, and bending sideways (40 minutes) as well as games such as relay races in which all the girls had to take an active part for about 20 minutes.

Measurements

Measurements for Part 1 (Community Home girls versus those from an ordinary school) as well as for Part 2 (Yoga versus Games groups of Community Home girls) were made under identical conditions. A moderately lit, sound-attenuated cabin was used for recording. After an initial period of 15 min. while sitting at ease, assessments were made for 10 min., also in the same Posture.

A 10-channel polygraph (Polyrite Recorders and Medicare, Chandigarh, India) was used to record the electrocardiogram (EKG), respiration, and the skin resistance. The EKG was recorded using standard limb lead 1 configuration. Skin resistance was recorded using silver chloride disc electrodes filled with electrode paste, and placed in contact with the volar surfaces of the distal phalanges of the index and middle fingers of the left hand. A constant current of 10 microamperes was passed between the electrodes. Respiration was recorded using a volumetric pressure transducer. Subjects were asked to stand erect and the transducer was fixed around the trunk, approximately 5 cm below the lower costal margin.

Data extraction and analysis

Data extraction was carried out similarly for both parts of the study. Polygraphic data were scored "blind" as follows. The heart rate (in beats per minute), was obtained by counting the number of QRS complexes in successive 60-sec. epochs continuously. The skin resistance (in kilo ohms) was sampled at 20-sec. intervals continuously. The breath rate (in breath cycles per minute) was obtained by counting the breath cycles in 60-sec. epochs continuously. For each subject the average of the values obtained during the 10-min. recording session were analysed.

The data of girls from the community home were compared with those of regular school girls of the same age using the Mann-Whitney U test. The data of both groups obtained at the end of six months were compared with their respective baseline data using the Wilcoxon paired-sample test.

RESULTS

Part I

The breath rate of the Community Home group was significantly higher than that of the group from a regular school using the Mann-Whitney U test [U value obtained is 348. for $n_1=n_2$=number in each group=20, U=319 at .001 (two-tailed) probability level, hence $p<.001$]. Also, skin resistance of the Community Home group was significantly lower than that of the regular school group [U value obtained is 272. For $n_1 = n_2 = 20$, U= 262 at the .05 (one-tailed) probability level, and U=273 at the .05 (two-tailed) probability level, hence $p < .05$]. The group mean values ± SD are presented in Table 1.

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TABLE 1: Means and standard deviations for Heart rate, Respiratory rate, and Skin resistance values in Community Home Girls and those from a Regular Schools

Group	n	Heart Rate (bpm)		Respiratory Rate (breaths/min.)		Skin Resistance Kilo ohms	
		M	SD	M	SD	M	SD
Community home	20	81.9	12.2	22.5	4.2**	105.7	72.2*
Regular	20	80.0	11.7	18.3	2.4	117.9	162.0

**p<.05, One tailed. **<.001, two-tailed Mann-Whitney U test*

Part II

There was a significant decrease in the heart rates of both Yoga and Games groups of Community Home girls at the end of six months compared with their respective baseline values, using the Wilcoxon paired-sample test [T= 1 for the Yoga group and T= 2 for the Games group. For n

TABLE II: Heart Rate, Respiratory Rate, Skin Resistance Values in Yoga and Games Groups or Community Home Girls at the Beginning (1) and End (2) of Six Months

Group	n	Time	Heart Rate		Respiratory Rate		Skin Resistance	
			M	SD	M	SD	M	SD
Yoga	20	1	81.0	8.3	22.5	2.1	105.0	79.2
	20	2	67.2	8.6+	21.3	2.3*	121.5	72.4
Games	20	1	80.3	14.5	22.5	4.9	125.3	68.5
	20	2	69.4	10.3+	21.2	3.9	100.2	81.6

**p< .02 + p<.001 Wilcoxon paired sample - test*

(number of pairs)=14, T=4 at the .001] two-tailed probability level, hence P< .001. The Yoga group alone showed a significant reduction in the breath rate [T value obtained is 14. For n = 14, T= 15 at the .02 (two-tailed) probability level, hence p <.02]. The group mean values + SD are presented in Table 2.

DISCUSSION

Part 1 showed that the Community Home girls had significantly higher breath rates and lower skin resistance values than the girls of the same age and economic status, who were attending a regular school and living at home. Visual inspection of the records of the Community Home group also showed more irregular breath patterns. Fear and anxiety were likely bases for irregular breathing with a characteristic pattern, i.e., very rapid and jerky (Ax, 1953; Bloch, Lemeignan & Aguilera-T, 1991). Such signs of arousal are in keeping with the higher electromyography tone reported for boys in a community home in Finland (Rauhala, et al., 1990). Inspection of the data of the Community Home girls indicated no differences between girls who were from broken homes and whose families visited them in the home. Also, the polygraphic data of the girls who had been in the home for less than six months were not different from those of girls whose stay was longer, e.g., 36 months. A previous study (Garralda, Connel, & Taylor, 1991) showed differences in autonomic reactivity (based on skin conductance and heart rate) for children with emotional and conduct disorders. Children with emotional disorders were more reactive to aversive events, whereas conduct-disordered subjects showed increased reactivity to pleasant situations.

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It was also mentioned that the baseline heart rates were significantly higher in the more severely affected of the emotionally disordered group, compared with those with lower scores.

The present Community Home girls did not have significantly higher heart rates than the other group. However, if the rapid and irregular breathing and lower skin resistance values are interpreted as signs of high psychophysiological arousal, the Community Home girls could be speculated to have emotional disturbances.

After six months of practice of the yoga or games significantly reduced the Community Home girls' heart rates. The yoga group only showed a significant reduction in the rate of respiration after 6 mo. The spirogram also showed that breathing was more regular in this group after 6 mo. The skin resistance did not change significantly for either group, although the Yoga group showed a nonsignificant increase however, that of the Yoga group was lower initially. Most children of both groups reported subjective feelings of well being at the end of 6 mo.

The heart-rate reduction for both groups could be anticipated from previous reports which indicated that a decrease in heart rate can occur with the practice of both yoga (Wallace, et al., 1971; Joseph, et al., 1981) and games (Williams & Sperryn, 1962). The effects of yoga and games in reducing the rate of breathing have also been reported. The practice of yoga reduced the breath rate, both as an immediate effect (Wallace, et al., 1971) and over 3 mo. (Joseph, et al., 1981). Similarly, athletes have lower breathing rates than those who do not have regular exercise (Shephard, 1966). In the present study six months of yoga practice reduced the breathing rate and irregularity of breathing, while increased physical activity for the same period did not have the same effect. In trying to explain this, two factors may be considered. The significantly more rapid (and more irregular) breathing of the Community Home group suggests that observations, e.g., increased physical activity reducing breath rate (Shephard, 1966) based on studies conducted on normal volunteers may not be applicable. Also, the two programs emphasized different factors (physical activity or relaxation). An earlier study (Rauhala, et al., 1990) had shown the efficacy of a carefully designed training program in reducing signs of stress in boys of a community home. This program consisted of increased physical activity through various aerobic exercises (jogging and swimming) as well as a form of relaxation which involved alternately contracting and relaxing different groups of muscles. Subjects were unable to relax with conventional relaxation exercises.

In the present study, given the yoga program's emphasis on relaxation and awareness, the subjects reported being able to relax perhaps because the yogasanas did involve at least minimal physical activity with instructions to relax throughout. In this way, subjects may have been better prepared for the 10-min. relaxation ("shavasan" or corpse posture) at the end of each session. The duration for which subjects had to remain in a particular posture was gradually increased as relaxation was maintained. These results suggest that a program which includes relaxation, awareness, and graded physical activity may be a useful addition to the routine of children resident in a community home.

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EFFECTS OF YOGA ON SCHIZOPHRENICS

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INTRODUCTION

Meditation has been gaining popularity as a psychotherapeutic intervention (Frith et al, 1979). However adverse effects of meditation have also been reported, viz. depersonalisation, altered reality testing, and the appearance of previously repressed, highly charged memories and conflicts (Glueck & Stroebel, 1976; Kennedy, 1976). Another report described how acute psychotic episodes were precipitated by intensive meditation in patients with a history of schizophrenia (Hasarus, 1976). Nevertheless the practice of yoga has potential benefits in schizophrenia by increasing the awareness (internal and external) along with relaxation. Hence the present study was designed to assess the benefits of diverse yoga practices in a mixed group of schizophrenics. Both clinical assessment and psychophysiological recordings were used to monitor their progress. In particular, since the electrodermal activity have already been widely studied in schizophrenics (Merkin 1985), the present study included a polygraphic recording of the skin resistance level (SPL) in these patients.

MATERIALS & METHODS

Patients

A mixed group of 23 schizophrenics (nine female subjects) aged between 25 to 48 years were initially included in the study. Seven of them were chronic schizophrenics. Twelve patients were on anti - psychotic medication at the time of assessment. All of them were staying at a halfway home. The patients were informed about the study and about the plan to introduce yoga in their program. They were encouraged to interact with the yoga instructor and to seek clarifications about any queries they had.

Design

Baseline assessments were carried out on 23 patients. Subsequent follow-up assessments were carried out after 4 months, 6 months, and 12 months. During this period all 23 subjects learned yoga and practised for 5 days per week. It was not possible to have a 'control' group who did not learn yoga, as the patients constituted a close community and excluding or including persons in any program was discouraged. Each subject was studied in a 30-minute session. Subjects were asked to relax (supine), with eyes closed.

Parameters

Polygraph assessments were made using a 10-channel polygraph. The electrocardiogram (EKG) was recorded using a standard limb lead 11 configuration. Respiration was recorded with a nasal thermistor worn at the nostril as a clip. Skin resistance was recorded using AgCl disc electrodes

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filled with electrode jelly, attached to the volar surfaces of the distal phalanges of the index and middle fingers of the right hand. A photo plethysmogram worn on the left thumb recorded the blood flow. Electroencephalogram (EEG) and electro oculogram (EOG) were recorded using conventions described elsewhere (6). EEG was recorded from the vertex (i.e. Cz), referenced to the left earlobe. EOG of left and right eyes were recorded on two separate channels.

Data extraction and analysis: EEG and EOG channels were scanned to detect (and exclude) any sleep episodes. Heart rate (HR) was calculated by counting the number of QRS complexes in successive 60 second epochs continuously. Breath rate was similarly obtained as the number of breath cycles in 60-second epochs continuously. The skin resistance level (SRL) in Kilo Ohms

TABLE 1 : Heart Rate (HR), Breat Rate(BR), Skin Resistance Level (SRL) & Skin Resistance Fluctuation Value (FV) In 11 Schizophrenic Patients At The Beginning & End of One Year. Values Are Group Mean (SD)

	HR (Beats per min.)	BR (Cycles per min.)	SRL (Kilo Ohms)	FV (Kilo Ohms)
Baseline	62.6 (13.7)	12.9 (4.3)	269.7 (169.0)	209.4 (186.1)
After 1 yeare	66.7 (14.0)	14.7 (3.8)	262.5 (99.1)	61.5 (45.6)

$p<0.01$ Two tailed t test "Baseline" versus "After 1 year"

was sampled every 20 seconds. The difference between the highest and lowest value of a subject was the fluctuation value (FV). The data obtained at the end of 4 months and 12 months were compared to the respective base line data using the t test (paired).

RESULTS

The groups mean values are provided in Table 1. The data showed that on the baseline assessment the skin resistance fluctuation value (FV) was higher for the schizophrenic population, than the norms. However no actual statistics were used.

There was a significant reduction in the FV at the end of 4 months ($P<0.05$, two tailed t test), which was more marked (after 12 months, $P<0.01$, two tailed t test).

DISCUSSION

The present study assessed the benefits of yoga practice on schizophrenic patients. Polygraph assessments showed that the fluctuations in the skin resistance level reduced significantly after 4 months of practice. This was more marked at the end of 12 months. The significance of high fluctuations in the SR of schizophrenics has been interpreted differently. Hyper responding acutes were reported to have positive symptoms, whereas hypo responding was associated with negative symptoms, (Walsh and Roche 1979). Also, acutes with positive symptoms tend to overrespond, whereas chronics with negative symptoms were found to under respond (Zahen et al. 1981). It was noted in the present study that at the end of four months several hyporesponders showed a normal response whereas hyperresponders showed a reduced response. This was interpreted as a 'stabilising' effect. At the end of 12 months, 11 of the subjects could be assessed. Of the remaining some had left the home, others were unwell (unrelated ailments, e.g. common cold), and for

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technical reasons assessments were not possible in another 5 patients. This one year follow-up included mainly the hyper responders, who all showed a decrease in fluctuation value (FV).

Subjective assessments showed that initially many of the patients were enthusiastic about starting a novel program, though an equal number were suspicious and resisted the change in routine. Careful supervision and support was available for all the patients by the therapists of the home, continuously. In the initial phases (and upto 3 weeks) this was very necessary as the relaxation exercises with instructions about deep awareness, caused active introspection, in many patients. Most of them found the experience were revealing (giving them insights into their thoughts and feelings), but also very uncomfortable. Close support and supervision permitted the experiment to continue. After this initial 'stormy' period, the disturbances were fewer and overall, both the patients and the therapists felt a greater sense of calmness. It should also be remembered that the community home has an active therapeutic (holistic) program, and the other interventions would also have had a beneficial effect, thus making it difficult to study the effects of yoga in isolation, specially without a control group. In spite of this, the present results suggest that yoga - if practised with close supervision and support - have both objective and subjective benefits for schizophrenics.

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YOGA, PERCEPTION AND PERFORMANCE

a) Perception 1-4

b) Performance 5-12

c) Memory 13

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IMPROVEMENT IN VISUAL PERCEPTION FOLLOWING YOGA TRAINING

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Visual discrimination was tested in two groups of 18 College students each, with ages ranging from 17 to 22 years. One group (the 'yoga' group) had 10 days training in yoga. Including asanas (physical postures), pranayama (voluntary regulation of breathing), tratakas (visual focusing exercises), meditation, and lectures on the theory of yoga. The control group carried on with their routine activities. The ability to detect intermittent light of fixed luminance, at varying frequencies was tested in both groups at the beginning and end of 10 days. While Initial values were similar for both groups. at the end of 10 days the frequency at which the yoga group was able to detect the flickering of the stimulus, was significantly more than the initial values (Wilcoxon's paired signed ranks test), whereas the control group showed no significant change. The final value of the yoga group was also significantly more than that of the control group (t test for unpaired data).

Meditation has been described as a training in awareness, which when kept over long periods produces definite changes in perception, attention, and cognition (Brown, 1977). Significant changes were reported in the visual perception of advanced meditators, who were able to distinguish subtle differences in color and shade, and were on the whole more perceptually sensitive (Brown & Engler, 1980). Another study described an increase in visual sensitivity following the practice of the mindfulness Buddhistic meditation (Brown, Forte & Dysart, 1984.) Subjects were able to detect shorter light flashes, and they required a shorter interval to differentiate between successive flashes correctly. In contrast the control group did not change.

It has also been shown that processing of sensory information at the thalamic level is facilitated during the practice of pranayama (Telles et al. 1992), and meditation (Telles & Desiraju, 1993, Telles et al. in press) These two practices, along with physical postures (asanas), cleansing practices (kriyas), devotional sessions, and lectures on the theory and philosophy of yoga were found to bring about an improvement in hand steadiness in college students following 10 days of practice (Telles et al. 1993). This improvement was believed to be due to improved eye-hand co-ordination, attention, concentration, and relaxation, as well. Hence the present study was carried out to assess whether practising the same yogic techniques for 10 days would significantly alter visual perception.

METHOD

Sample

There were 2 groups of subjects (with ages ranging from 17 to 22 years). Each group had 18 subjects, of whom 3 were females. One group participated in a 10 day residential camp in yoga. The control group, like the yoga group were university students.

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Testing Procedure

Critical flicker frequency was measured using the apparatus fabricated by Anand Agencies (Pune, India), which has a red light stimulus (6mm in diameter) with intensity of approximately 06 mw/ cm2 at a flash frequency from 12-95 cycles per second. Each subject was tested individually with binocular vision. The apparatus and subjects eyes were kept on the same line of vision and were 50cm apart. During the experiment all overhead lights were switched off except one 60w bulb to maintain a constant background illumination.

Assessments were made for both groups ('yoga' and control) at the beginning and end of 10 days. During the 10 day period the 'yoga' group received training in yoga, whereas the control group did not receive such training and carried on with their routine activities. The initial and final values were compared for significant differences using Wilcoxon's paired signed ranks test.

The yoga group received 10 days training in asanas (physical postures), pranayarna (voluntary regulation of breathing), kriyas (cleansing techniques including visual focusing exercises used to improve visual acuity and mental concentration), meditation, devotional sessions, and lectures on the theory and philosophy of yoga. This programme took approximately 8 hours a day.

RESULTS

Both groups ('yoga' and control) had approximately similar values of critical flicker frequency (CFF) on initial testing (group mean $\pm$ SEM, 37.6 ± 0.7, and 37.9 ± 0.6, respectively). At the end of 10 days, the CFF of the yoga group had significantly increased to 42.6 ± 1.6 ($p<0.01$, Wilcoxons paired signed ranks test), whereas the control group showed no significant change (38.4 ± 0.7, $p>0.5$, Wilcoxon's paired signed ranks test). The final value of the yoga group was also significantly more than that of the control group ($p<0.001$, t test for unpaired data).

DISCUSSION

The CFF depends on a variety of factors, such as stimulus characteristics, concurrent stimulation of other sensory modalities, temperature, body position, and diurnal rhythms (Graham, 1965). In the present experiment stimulus parameters were kept constant. Also other sensations were cut-off by carrying out both initial and final tests under constant illumination and in a sound-attenuated room, with temperature maintained constant, and the subject seated in a comfortable position. The time of testing was also kept the same. Other factors which influence CFF are the levels of concentration, attention, and relaxation. These factors could have influenced the CFF favourably in the present study. Apart from this, temporal resolution of visual stimuli is often limited by the brain rather than the eye (Riggs, 1992). The improvement could be related to enhanced neural processing at the thalamic level which occurs during pranayarna and meditation (Telles et al. 1992, Telles et al., in press).

Hence the significantly higher CFF levels seen after 10 days of yoga training could be due to diverse factors, ranging from more efficient processing of sensory information in the brain to increased attention, concentration, and simultaneous relaxation with yoga.

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IMPROVEMENT IN VISUAL PERCEPTUAL SENSITIVITY IN CHILDREN FOLLOWING YOGA TRAINING

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A sample of 14 children with ages ranging from 12 to 17 years (6 females) who received 10 days of yoga training and another 14 age and sex matched controls who did not receive yoga training were assessed on Day 1 and Day 10 for visual perceptual sensitivity through Critical Flicker Fusion Frequency (CFF) and degree of illusion. Yoga group practised yogasanas, pranayama, kriyas, meditation and bhajans along with specially designed games to improve memory and attention. The control group carried on with their routine Activity. Following 10 days of yoga training, yoga group showed a significant increase in CFF (9.2%) and decrease in degree of illusion (24.89% for in trails and 31.05% for out trails), while the control group showed no change. Thus the present study suggests that younger subjects can show better improvement in performance in a relatively short duration as compared to previous reports.

Meditation has been shown to bring about significant changes in perception, attention and cognition (Brown, 1977). That yoga practice increases visual perceptual sensitivity, has been experimentally proved using different methods of assessment. Meditators were found to be more sensitive to, subtle aspects of color and shading of the Rorschach test inkblots than they had been before meditation (Brown, 1980). Two separate studies on Critical Flicker Fusion Frequency (the frequency at which a flickering stimulus is perceived to be steady, with higher values suggesting greater perceptual accuracy) have shown that perceptual sensitivity is not restricted to subtle aspects of the stimulus alone, as detection of a high frequency flickering stimulus was found to improve following yoga training (Ramana et al., 1997; Telles at al., 1995). A study on degree of visual geometric illusions, based on the Muller-Lyer apparatus suggested that a combination of focusing and defocusing through yoga reduces optical illusion more than focusing alone (Telles et al., 1997). These studies were conducted on adult subjects with varying durations of yoga training. Hence the present study was planned to assess visual perceptual sensitivity to Critical Flicker Fusion Frequency and degree of optical illusion in children following 10 days of yoga training.

METHOD

Subjects

14 children (6 female) with ages ranging from 12 to 17 years (group mean = 14.5, SD $\pm$ 1.5 years) received 10 days training in a combination of yoga practices. A group of 14 age and sex matched children who did not receive training in yoga were followed up for comparison and to see the retest effect. All subjects had normal vision without correction and none of them had color blindness. The latter was measured in view of the fact that the color of the stimulus has been reported to influence the CFF (Ali, Jahan & Chowdary, 1986).

Design

Both groups (yoga and control) were assessed on Day 1 and Day 10. The yoga group was attending a 10-day residential yoga camp, while the control group carried on with their routine activities.

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Assessments

(i) Critical Flicker Fusion Frequency (CFF): CFF was measured using a standard electronic apparatus (Fritze & Simonson. 1951) (Anand Agencies, Pune, India). This apparatus consists of a red stimulus (6 mm in diameter) in the center, with a luminous intensity of 50 mcd and flicker frequency, which can be, adjusted from 12 to 95 Hz. A white background with illumination of 150 lux surrounded the stimulus. The subject was seated at ease 50 cm in front of the apparatus (i.e., 80 cm from the stimulus). The experiment was conducted with a minimal illumination of a 40-w bulb fixed behind the subject and the light dark ratio was kept as 1 (50:50). The binocular response of all subjects was assessed in both ascending and descending trials as described, according to the standard methodology (Ramana et al., 1997').

(ii) Muller-Lyer Apparatus: The degree of optical illusion was measured using the Muller-Lyer apparatus (Anand Agencies, Pune, India). The Muller-Lyer lines though of equal length, appear unequal due to the two different types of arrows drawn at both ends of the line: closed-ended arrows making an acute angle or open-ended making an obtuse angle with the shaft. One line was of fixed length with close-ended arrows giving it an illusionary shorter appearance, while the length of the other line could be varied. This line had open-ended arrows giving it a longer appearance. The subjects were seated 1.8 m away from the apparatus, while the experimenter manipulated the length of the line according to the subject's specifications. The exact position at which the subject perceived the two lines to be of equal length was noted, i.e., subjective reading ("Sr'). The difference between the 'Sr' and the reading, at which the lines were actually of equal length, gave the degree of illusion ('di'). The degree of illusion perceived using Muller-Lyer lines in both ascending and descending trials were recorded using method described previously (Telles et al., 1997). Data al the end of 10 days were compared with initial data using the 't' test for paired data.

Yoga Training

The yoga group received yogic training for approximately 8 hours a day, aiming at their all round (physical, mental, intellectual and spiritual) development. The 10-day Program consisted of (1) Yogasanas, specialized physical postures; (2) Pranayama or voluntary regulation and slowing of the breathing: (3) Kriyas, internal cleansing practices including eye-cleansing techniques (trataka); meditation and bhajans. In addition to these specialized practices, the training also included games to improve the attention span and memory as well as telling of meaningful stories to foster a sense of values and feelings of responsibility (Telles et al., 1993).

RESULTS

There was a significant increase in Critical Flicker Fusion Frequency in the group who received yoga training ($P < .005$, 't' test for paired data) and a significant reduction in the degree of optical illusion perceived by the same group ($p < .005$, for In trials and $p < .005$ for out trials, 't' test for paired data). The control group (without yoga training) showed no significant change.

The group mean values of CFF and degree of illusion ("di") for both in and out trails ± SEM of both yoga and control groups on Day 1 and Day 10 are provided in Table1.

DISCUSSION

Yoga training of children for 10 days resulted in a significant improvement in, visual perceptual sensitivity as measured through Critical Flicker Fusion Frequency and the degree of optical illusion. The control group who did not receive yoga showed no change.

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TABLE 1

Group Mean Values of CFF and Degree of Illusion ("di") for both In and Out Trials ± SEM of Yoga and Control Groups on Day 1 and Day 10

CFF			Day 1	Day 10
(n = 14)		Yoga group	35.55 ± 2.30	8.42** ± 1.80
		Control group	35.54 ± 1.90	35.42 ± 1.40
Degree of Illusion (di) (in mm) (n=14)	In trials	Yoga group	38.36 ± 2.10	28.81* ± 2.80
		Control group	36.06 ± 0.90	35.75 ± 2.90
	Out trials	Yoga group	42.64 ± 1.90	29.40** ± 3.10
		Control group	43.91 ± 0.90	42.51 ± 2.90

Previous studies on adults with varying durations of yoga training showed improved visual perception (Ramana et al., 1997; Telles et al., 1997). There was a graded increase in CFF on days 20 (11.16%) and 30 (14.96%) as compared to day 10 (9.2%). The present study showed similar percentage of improvement in CFF (9.2%) after 10 days, as compared to the previous study (Ramana et al., 1997), and was statistically significant. The increased CFF following yoga could be attributed to the effects of yoga in reducing physiological signs of stress, such as decrease in heart and breath rate and in oxygen consumption (Joseph et al., 1981), as CFF was found to be lower during specific stressors, such as food and water deprivation (Ali & Amir, 1989). The non-significant improvement in CFF in the previous study on Day 10 as compared to another study (Telles et al., 1995), which showed a significant improvement on Day 10, was correlated to the difference in their age groups. The subjects of the former study were of the age group 25-39 years while the latter study had subjects of 17-22 year age group. Hence the significant changes in CFF in the present study suggests that younger age group could improve in performance following a shorter duration of yoga, compared to older subjects.

A previous report on optical illusion suggests that one month of yoga brings about an 86.2% decrease in the degree of illusion perceived (Telles et al., 1997). The present study in children following 10 days of yoga also showed similar results, but was of lesser magnitude (27.9 %).

The decrease in the degree of illusion perceived over a short period would be mainly due to cognitive judgemental factors, but not retinal or cortical factors as generally understood (Coren & Girgus, 1973). The cognitive judgmental factors involve the way in which the subject interprets incoming visual information based on experience, hypothesis and strategies of judgement. Hence the training through yoga to focus and defocus might have influenced the cognitive judgmental factors of the subjects, to significantly reduce the degree of illusion perceived.

Hence yoga training showed improvement in the subjects visual perceptual sensitivity. The present study suggests that younger subjects can show better improvement in performance following yoga training of a relatively short duration.

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Indian J Physiol Pharmacol 1997; 41(2): 179-182

SHORT COMMUNICATION

A COMBINATION OF FOCUSING AND DEFOCUSING THROUGH YOGA REDUCES OPTICAL ILLUSION MORE THAN FOCUSING ALONE

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(Received on February 19, 1996)

Abstract: The degree of optical illusion was assessed using standard Muller- Lyer lines in two groups (yoga and control) of thirty subjects each. All subjects were between eighteen and forty two years of age. The difference between the reading at which the lines were actually equal and the reading at which the subject felt them to be equal, was noted as the degree of illusion ("di"). Each subject was assessed at the beginning and end of a month. During the month the yoga group received training in yoga, while the control group carried on with their usual routine. At the end of the month the yoga group showed a significant (two factor ANOVA, Tukey test, $P < .001$) decrease in the "di' (86%), whereas the control group showed no change. The improvement following yoga could he attributed to the combination of focusing and defocusing involved in yoga practice, as these factors are known to influence the 'di'. Previous results which mentioned a 79% decrease in "di" with focusing alone, provided a comparison.

Key words: *optical illusion; defocusing; Focusing; yoga.*

INTRODUCTION

When an observer views certain patterns and is asked to describe them, the subjective assessment of the size, shape or direction of pattern components often differs from what might be expected based on direct physical measurements of the stimulus. These patterns are called visual-geometric illusion (1). With greater accuracy of perception there will be an increasingly smaller disparity between the actual stimulus and what is perceived.

Perception of a geometric illusion is influenced by retinal, cortical and cognitive- judgmental factors (2).

It has been shown that training in focusing the gaze on the stimulus reduces the optical illusion by 79 percent (3). The present study aimed at assessing the effect of yoga practices (which involved both focusing and defocusing of the gaze and the attention), on the degree of optical illusion perceived.

METHODS

Subjects

There were two groups (yoga and control) of 30 subjects each. The subjects of both groups were matched for age and sex, with ages ranging from 18 to 42 years (group average age ± SD, 28.8 ± 6.1 years) and 6 female subjects in each group. All subjects had normal vision without correction.

Corresponding Author

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Apparatus

The degree of optical illusion was measured using the Muller-Lyer apparatus (Anand Agencies, Pune, India). The Muller-Lyer lines though of equal length, appear unequal due to the two different types of arrows drawn at both ends of the line: close-ended arrows making an acute angle or open-ended arrows making an obtuse angle with the shaft. In the apparatus used for the present study the line on the left was of fixed length and had close- ended arrows at either end giving it an illusory shorter appearance. In contrast the length of the line on the right could be varied. This line had open-ended arrows at either end which made it appear longer.

Assessment procedure

The experimenter manipulated the length of the line according to the subject's specifications. The exact position at which the subject perceived the two lines to be of equal length was noted, i.e. subjective reading ('sr'). The difference between the 'sr' and the reading at which the lines were actually of equal length, gave the degree of illusion ("di"). Each subject was assessed in two types of trials ('in" and 'out'), ten each, given alternately. For 'in' trials the examiner adjusted the length from maximum (200 mm) till the subject, seated 1.8 m away, perceived the length to be equal to the fixed line (160 mm). For 'out' trials the procedure was reverse, the adjustable line was kept to minimum length and the length was gradually increased till the subjects perceived the length to equal that of the fixed line. In both cases the difference (in mm) between actual length of the line and the perceived length was noted as the degree of illusion ("di").

Design of the study

Subjects of both groups were assessed at the beginning and end of a month. During the month subjects of the yoga group received training in yoga, whereas control group subjects carried on with their routine activities.

Yoga training

The yoga group received training in physical postures (asanas, 90 min), yoga voluntary regulated breathing (pranayama, 60 min), meditation (60 min), lectures on the theory of yoga (60 min), as well as visual cleansing exercises (trataka, 30 min). During trataka and meditation, subjects were given instructions to focus the gaze on a specified object, followed by defocusing. During asanas and pranayama practice subjects were asked to "focus" their attention (on their breathing or body sensations), followed by "defocusing".

Data analysis

The data were analyzed using the two factor ANOVA, where Factor A = Yoga versus Control group; Factor B = before versus after. Separate two factor ANOVA were performed for the data obtained during "in" and & "out" trials. The Tukey multiple comparison test was used to test for significant differences between group average values.

RESULTS

The two factor ANOVA (Factor A = Yoga versus Control groups and Factor B = before versus after) revealed significant differences ($P<.001$, all cases) for both factors as well as the interaction between them (A X B), for "in" and 'out' trials, calculated separately. See Fig. 1 for group average values of the degree of illusion ('di"), in mm. The Tukey test results are summarized in Table 1.

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Indian J Physiol Pharmacol 1997; 41(2)

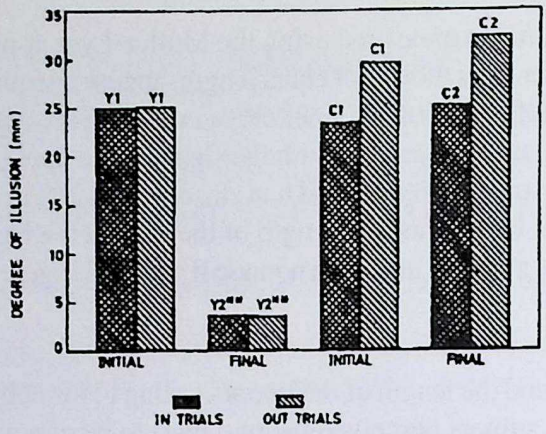

*Fig. 1: Group average degree of illusion ("di" in mm) in yoga (Y) and control (C) groups at initial (1) and final (2) assessments, during both "In" and "Out" trials. ** = P< 0.001, Tukey test (Y2 versus Y1, or Y2 versus C2, or Y2 versus C1). The standard deviation (SD) values for the Y group at 1 and 2 testings were 1.4 and 1.0, respectively, for both trials. For the C group the SD values at 1 and 2 assessments were 1.7 and 1.5 respectively (" In trials") and 1.1 and 1.9 respectively ("out trials")*

Tabel 1 Tukey test results (q values) before (B) or after (A), yoga(Y) or control(C)

Sessions

Comparison	Out trial	In trial
BY versus AY	15.42**	16.77**
BC versus AY	9.03**	18.22**
AY versus AC	21.07**	18.30**
BY versus BC	2.51	1.44
BY versus AC	2.72	1.52
BC AC	2.20	1.51

***P<.001, where q (.001), 116,4 = 5.48; (derived value of q)*

DISCUSSION

The present study showed that a month of yoga training caused a significant decrease in the degree of optical illusion perceived using the Muller-Lyer lines. For "out' trials the decrease was 86.4% and for "in' trials it was 86.0%, hence the average decrease was 86.2%. A previous report described how focusing the gaze reduced the optical illusion by 79% (3). In the present study subjects of the yoga group were trained for a month in yoga practices which involved' actually focusing and defocusing the gaze on a specified object (as in trataka or meditation), or "focusing

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- defocusing" the attention on the breathing/body sensation's (as in asana and pranayama practice). Hence the combination of focusing followed by defocusing appears to be more effective in reducing the degree of illusion compared to focusing alone.

Retinal, cortical and cognitive-judgmental factors influence the perception of a geometric illusion (2). At the retinal level mutual inhibition of spatially adjacent neural units account for the perception of an illusion involving intersecting lines (4). A cortical "satiation" model has been proposed to explain the role of cortical factors in perceiving an illusion (5). It states that if a specific cortical locus is continuously stimulated the neural substrate becomes refractory and hence difficult to activate. This refractoriness spreads spatially to include, nearby neural units. If a test line is presented so that the activation caused by it overlaps the refractory region, the response will be inaccurate and may result in an illusory perception.

Where there is a decrease in the degree of illusion perceived over a short period it is generally understood that retinal or cortical factors would not contribute to the change which would be mainly due to cognitive- judgmental factors (6). Changes within a month fall into this category, as opposed to changes taking place over one or more years. Cognitive-judgmental factors involve the way in which the subject interprets incoming visual information based on experiences, hypotheses and strategies of judgment. Hence in the present study the training in focusing defocusing through yoga for a month may have influenced the cognitive-judgmental factors of the subjects, to significantly reduce the degree of illusion perceived.

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PROGRESSIVE INCREASE IN CRITICAL FLICKER FUSION FREQUENCY FOLLOWING YOGA TRAINING

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Abstract: The critical flicker fusion frequency (CFF) is the frequency at which a flickering stimulus is perceived to be steady, with higher values suggesting greater perceptual accuracy. The CFF was measured in two age-matched groups of healthy male volunteers whose ages ranged from 25 to 39 years, with 18 subjects in each group. After baseline assessments one group (yoga group) received yoga training, while the other group (control group) carried on with their routine activities. Yoga practices included asanas, pranayamas, kriyas, meditation, devotional sessions and lectures on the theory of yoga. After 10 days neither group showed a change in CFF. However, at 20 and at 30 days the yoga group showed significant increases in CFF by 11.1% and 14.9%, respectively (two factor ANOVA, Tukey multiple comparison test). The control group showed no change at the day 20 and day 30 followup.

Key words: *critical flicker; fusion frequency; visual perception; Yoga.*

INTRODUCTION

Meditation has been reported to cause significant changes in perception, attention and cognition (1). The increased sensitivity following meditation has been experimentally proved with different assessment criteria. The Rorschach test was used as a perceptual test and meditators were more sensitive to subtle aspects of colour and shading on the inkblots than they had been before meditation (2). This perceptual sensitivity was not restricted to subtle aspects of the stimuli, as detection of a high frequency flickering stimulus or the critical flicker fusion frequency (CFF) was found to improve (3). The CFF indicates the frequency at which a flickering light is perceived to be steady. Two possible physiological explanations for the "fusion" of a flickering stimulus, involving the peripheral visual pathway are as follows, viz (i) the frequency at which the optic tract discharges may limit the ability to perceive high frequency light stimuli and (ii) ganglion cells of the "on-off" variety, which discharge when illumination comes on and goes off produce a response which is indistinguishable from their discharge under steady illumination, at a frequency of about 35 flashes per second (4). In contrast to these explanations based on properties of the peripheral visual system being responsible for the phenomenon of flicker fusion, electrical recording at various levels of the visual pathway in both animal and human subjects have shown that the eye itself may respond at higher frequencies than the value of the CFF obtained by behavioural or psychophysical techniques, and is hence not the limiting factor in determining the CFF. This lead to the conclusion that temporal resolution of the flickering stimulus is often limited by the brain rather than the eye (5).

In the study cited above (3), 10 days of yoga training increased CFF, whereas a group which did not practice yoga but was retested at the same time showed no change. In attempting

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to explain this effect of yoga practice, it may be recalled that the effects of yoga in reducing physiological signs of stress, such as a decrease in heart and breath rate, and in oxygen consumption are known (6). This may be relevant because the CFF was found to be lower during specific stressors, such as food and water deprivation (7). The mechanisms for this have not been worked out.

With this background, the present study was conducted with the following aims and objectives: (1) To assess the effects of yoga training on the critical flicker fusion frequency (CFF), and compare these effects with retest without any intervention (control group) (2). To assess the effects of different durations (i.e. 10, 20 and 30 days of yoga training) on the CFF.

METHODS

Subjects

There were 2 groups of healthy male volunteers, i.e. yoga and control groups, with 18 subjects each. The yoga group was attending a one-month residential yoga training program. The age range was 25 to 39 years, with group average ± SD, 33.9 ± 4.5 years.

The non-yoga (control) group was selected to exactly match the yoga group for age. These subjects were working and residing close to the yoga center. Hence both groups stayed in a quiet, rural area. The subjects of both groups also had comparable social and educational backgrounds. All subjects had normal vision without correction and none of them had colour blindness. The latter was measured in view of the fact that the colour of the stimulus has been reported to influence the CFF (8).

Design of the study

Both groups were assessed four times each, under similar conditions. Baseline assessments were made at the start of the study. After this the yoga group received training in yoga, while the control group carried on with their routine activities. Subsequent assessments for both groups were made after 10, 20 and 30 days.

Assessment procedure

Critical flicker fusion frequency was measured with a standard electronic apparatus (9) (Anand Agencies, Pune, India). This apparatus has a red light stimulus, 6 mm in diameter, with a luminous intensity of 50 mcd and flicker frequency which can be adjusted from 12 to 95 Hz. The stimulus was surrounded by a white background with illumination of 150 lux. The subject was seated at ease 50 cm in front of the apparatus (i.e. 80 cm from the stimulus). During the experiment all overhead lights were switched off except for a 40-w bulb fixed behind the subjects. The light: dark ratio was kept as 1 (50:50). The binocular response of all subjects was assessed in two types of trials: [i] ascending: the frequency of flicker was gradually increased, 0.5 Hz per step, from the minimum (12 Hz) till the subjects reported that it was " fused" or steady, this was the fusion threshold, and [ii] descending the frequency of the response was gradually reduced (0.5 Hz per step) from maximum (95 Hz) till the subjects reported that it was flickering, this was the flicker threshold. Each subject was assessed in 20 trials each, i.e. 10 ascending and 10 descending, given alternately. The values obtained in both types of trials were considered together and out of the 20 values obtained for each subject, the value to be used for statistical analysis was selected as follows: when at least 3 successive readings were the same or with not more than 0.5 Hz between them, this value was noted as the critical flicker fusion frequency or CFF (10).

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Yoga training

The yoga group received training in physical postures (asanas, 90 minutes), cleansing practices (kriyas, 30 minutes), yoga voluntarily controlled breathing (pranayama, 60 minutes), meditation (60 minutes), devotional sessions (90 minutes) and lectures on the theory of yoga (60 minutes).

Data analysis

The CFF values of the two groups obtained with 4 assessments were compared for significant difference using a two factor ANOVA, where Factor A = yoga versus control group, and Factor B = the 4 assessments (baseline, day 10, day 20, day 30). The group mean values were compared for significant differences using the Tukey, multiple comparison test.

RESULTS

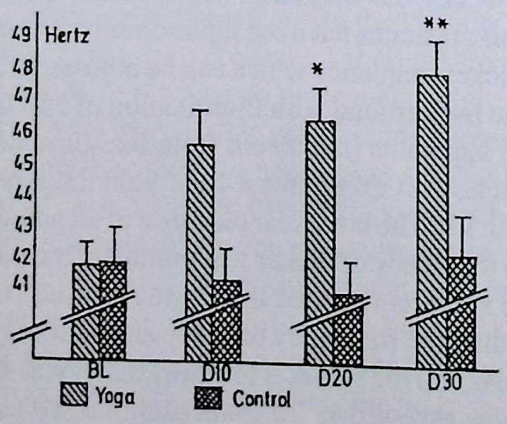
The two factor ANOVA

Showed a significant difference between yoga and control groups, i.e. Factor A. [F = 27.9, the F value for DF = 1, 120 at the .001 level (two tailed) = 12.8, hence P < .001]. Here the actual DF = 1, 120 were chosen as the nearest values in the probability table]. The difference between the 4 assessments, i.e. baseline, day 10, day 20 and day 30 was also significant, i.e. Factor B [F = 5.3, the F value for DF = 1, 120 at the .005 level (two-tailed) = 5.05. Hence P < . 005]. The

Table 1: Group mean values of CFF (± SEM) for yoga and control groups at baseline (0 days), and after 10, 20 and 30 days.

	0 days	10 days	20 days	30 days
Yoga group (n = 18)	42.1±0.76	46.0 ± 0.90	46.8±1.0*	8.4±1.1**
Control group (n = 18)	42.1 ±1.0	41.6 ± 1.0	41.4±1.0	42.7±1.3

**P<.05, **P<.001 Tukey test comparison with day 0 value of the respectice group.*



CFF in Yoga and Control group

*Fig.1: Group mean critical flicker fission frequency (CFF) values ± SEM in yoga and control groups (18 subjects) for baseline (BL), days 10 (D 10), 20 (D 20) and 30 (D30). *P< .05, **P<.001) 1; D20 versus BL, D 30 versus BL respectively (Tukey test).*

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interaction between factors A and B (A× B) was not significant [F = 0.1, P> .51]. The group average CFF values ± SEM of the four groups at the 4 assessments are provided in Table 1, Fig.l.

The Tukey multiple comparison test

Showed significant differences between the CFF values of the yoga group at days 20 and 30, compared to the baseline reading (P< .05, P< .001, respectively). The day 10 - baseline comparison for both groups as well as other comparisons for the control group were not significant.

DISCUSSION

The present study showed a significant increase in critical flicker fusion frequency (CFF) of the yoga group after 20 and 30 days compared to the baseline. The CFF values of the control group did not change significantly on repeat assessment.

A previous study (3) had demonstrated a significant increase in CFF values after 10 days of yoga training (similar to the program in the present study). The increase was 5 Hz on an average. In the present study there was a non- significant increase at 10 days. The increase was 3.9 Hz on an average. The difference between the significant effect observed earlier, versus no change (or more accurately the non-significant, lower magnitude increase) in the present study could be related to the difference in age groups of the subjects of the two studies. Subjects of the earlier study were university students between 17 and 22 years of age, whereas the subjects of the present study were between 25 and 39 years, with an average of 33.9 years. It is established that the intra-individual variability of the CFF declines with age (11). This is true for the age difference between the earlier and present studies (average age 20 years versus 33.9 years, respectively). Hence any intervention (e.g. yoga) would be expected to cause smaller magnitude changes (i.e. less intra-individual variability) in the present subjects. The reason for the reduced variability is not clear, both peripheral (retinal) and central (sub-cortical, cortical) factors have been implicated. Hence the present subjects were less amenable to change in the CFF with yoga compared to the earlier group of younger subjects (3).

The absence of change in the control group showed that replications spaced 10 days apart do not increase CFF on retesting. Hence the increase in CFF after 20 and 30 days of yoga training can be attributed to yoga. While the mechanism underlying the change is not known, we may speculate that the increase in CFF may be due to the effects of yoga in reducing physiological signs of stress, such as a decrease in heart and breath rate, and in oxygen consumption (6). As already described (Introduction) this may be relevant because the CFF was found to be lower during specific stressors, such as food and water deprivation (7). Further studies are required to understand the mechanisms and identify whether a specific yoga practice is specially helpful or whether the effect depends on a combination of yoga practices.

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PHYSIOLOGICAL CHANGES IN SPORTS TEACHERS FOLLOWING 3 MONTHS OF TRAINING IN YOGA

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INTRODUCTION

Three months of training in the ancient Indian science of Yoga, which included different asanas (physical postures) and Pranayamas (voluntary regulation of the breathing) has following effects in normal, healthy subjects, viz a significant reduction in heart rate, BP and an increase in mean skin temperature, and alpha index of EEG, reduction in blood glucose, plasma cholesterol, dopamine B hydroxylase and monoamine oxidase, and increased levels of urinary 17-keto steroids. These changes were interpreted as a shift in autonomic equilibrium towards parasympathetic dominance. The present study was conducted to assess whether yogic training of the same duration (3 months) would cause physiological changes in 40 male physical education teachers whose ages were between 25 and 48 years (34.7 ± 5.9), and who had already been actively engaged in diverse physical activities for 8.9 + 5.8 years.

The subjects were attending a 3 month residential camp at the Vivekananda Kendra Yoga Research Foundation campus (Bangalore, India) to receive training to teach yoga in schools. Since it was a residential camp, the living conditions of the group were approximately constant. The Yoga training consisted of practice of different asanas (physical postures), Pranayamas (voluntary regulation of breathing), meditation, devotional sessions and lectures on the theory and philosophy of yoga. In addition, special emphasis was given to their grasping the total approach of Yoga to bring about eyesight improvement, voice culture, enhancement of physical stamina, memory and creativity, emotion culture, I.Q., Spiritual and personality development. The actual practices were as follows.(1) Asanas : (a) Those performed when standing - ardhakati - cakrasana, trikonasana and padahastasana. (b) Those performed when sitting - vajrasana, padmasana, yoga mudra, ustrasana, sasankasana, ardha matsyendrasana, pascimatanasana and suptavajrasana. (c) Those performed in the prone position were bhujangasana, dhanurasana, and relaxation in makarasana. (d) Asanas performed in the supine position - sarvangasana, matsyasana, halasana and relaxation in savasana. Usually asanas were performed between 5.30 am and 7.00 am everyday. (2) Pranayama practices included initial cleansing (kapalabhati) followed by sectional (i.e. clavicular, thoracic and abdominal) breathing, full yogic breathing and nadisuddhi pranayama. Pranayama was practised between 11 am and 12 noon, daily. (3) Kriyas or cleansing practices such as jala neti, sutra neti and vaman dhouti were practised two times a week. Also occular exercises (tratakas) intended to 'cleanse' the eyes and improve vision were practised for 20 min everyday. (4) Meditation was silent mental chanting of the syllable "OM" for about 15 mins. Also for 60 min everyday 'cyclic meditation' was carried out. This actually is based on

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'stimulation followed by relaxation', and at the end of the practice the subject lies in savasana (with instructions) to experience higher levels of expansion. (5) Devotional Sessions with singing bhajans, for 60 min daily. (6) Lectures usually 2 lectures per day, 60 min each.

The subjects were given 2 days to get accustomed to the routine of the camp, then the study, (which conformed to the ethics laid down by the Indian Council of Medical Research, New Delhi) was explained to them, and their signed consent was taken. On the third day the following parameters were assessed: forced expiratory volume in 1 sec (FEV_1), forced vital capacity (FVC) both recorded using (Vitallograph Ltd., U.K.), PEER (Mini Wright's peak flow meter), galvanic skin resistance and stethographic record of respiration using a 4-channel portable polygraph (Lafayette, U.S.A.), ECG (Lead 1) to derive heart rate by counting successive QRS complexes, using a clinical electrocardiograph (BPL, India), body weight, breath holding time and BP (sphygmomanometer record). All assessments were repeated twice on each subject initially and twice finally as well. Both recordings were made on the same day. Also the timings of the 2 initial recordings and the 2 final recordings were kept the same. In addition, the steadiness and co-ordination of the hands were tested with a 'steadiness' tester (Anand Agencies, Pune, India) according to the method described by Mellon. The total of 'errors' made by each subject initially and after 3 months of yogic training, were noted.

The data obtained at the end of 3 months was compared with that taken initially, using paired t-test (two-tailed).

Table 1. Changes in autonomic, respiratory, and general health parameters. (Mean ± S.E.) after 3 months yogic training in 40 male physical education teachers

Parameters	Initial Values	Values after 3 months Yogic training
Body weight (kg)	59.50+1.24	58.60±1.05*
Blood pressure (mm Hq)		
Systolic BP	127.10 + 2.54	117.80 ±1.28*
Diastolic BP	82.60 ± 2.08	75.60 ± 0.99***
FEV_1,(1 BTPS) FEV_1	2.20 ± 0.12	2.56 ± 0.08**
FVC (1 BTPS)	2.95 ± 0.13	3.48 ± 0.1 1 ***
FEV_1/FVC FEV_1/FVC	74.50 ± 2.48	74.30 ± 1.26
PFR (l/min)	499.10 ± 11.20	528.90 ± 10.90***
Breath holding time (sec)	35.60 ± 1.97	49.80 ± 2.44***
Heart rate (beats/min)	71.03 ± 1.48	68.00 ± 1.27*
Respiratory rate (breaths/min)	16.70 ± 0.82	14.30 ± 0.77*
GSR (Kilohms)	69.67 ± 6.80	77.35 ± 5.20
Steadiness test (Number of 'errors')	21.50 ± 1.21	17.40 ± 1.13*

** ='P<0.05; ** = p < 0.01" *** = <0.001 (Paired t-test, two tailed)*

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RESULT

There was a significant increase in PFR (60%) FEV_1. FVC (18%) (though FEV_1/ FVC % did not change), Breath holding time (40%), and a significant reduction in heart rate, respiratory rate, systolic and diastolic BP readings, body weight, and also in the number of errors made in the steadiness test (Table 1). There was a trend of increase in Galvanic Skin Resistance (GSR) reflecting reduction in sympathetic activity supplying the sweat glands. However this was not significant (paired t-test, two tailed) for the group as a whole. When the GSR data of each subject was analysed separately (Student's t-test, two tailed), it was revealed that at the end of 3 months, the subjects fell into 3 groups: (i) 21 subjects had increased GSR, (ii) 9 subjects had decreased GSR, and (iii) 10 subjects showed no change. On examining the GSR data of the subjects belonging to each of the 3 groups separately, it was observed that the subjects who showed increased GSR at the end of 3 months had lower initial values than the others (group average initial value ± S.E was 44.1±2.7 K Ohms) and after 3months the group average value S.E. was 82.0±4.7 KOhms. On the other hand, those who showed a decrease at the end of 3 months had higher initial values than the rest (group average initial value S.E. was 116.5±3.8 KOhms). Their final value (group average ± S.E. was 79.1 = 2.4 K Ohms). The subjects who showed no change had initial values in- between those of the other two groups (group average initial value ± S.E. was 82.0 ± 8.4 K Ohms) and this did not alter significantly after 3 months (group average ± S.E. was 74.0 t. 7.0).

Summary

1. This report shows that in a group of 40 physical education teachers who already had an average of 8.9 years physical training, 3 months of yogic training produced significant improvement in general health (in terms of body weight and BP reduction and improved lung functions).

2. There was also evidence of decreased autonomic arousal and more of psychophysiological relaxation (heart rate and respiratory rate reduction), and improved somatic steadiness (decreased errors in the steadiness test).

3. The changes at the end of 3 months in volar GSR in different directions (increase /decrease/ no change), depending on the initial values, suggests that practising yoga may help to bring about a balance in different autonomic functions, so that functioning is optimised.

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IMPROVEMENT IN STATIC MOTOR PERFORMANCE FOLLOWING YOGIC TRAINING OF SCHOOL CHILDREN

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Summary - *Two* groups of 45 children each, whose ages ranged from 9 to 13 years, were assessed on a steadiness test, at the beginning and again at the end of a 10-day period during which one group received training in yoga, while the other group not. The steadiness test required insertion of and holding for 15 see. a metal stylus without touching the sides of holes of decreasing sizes in a metal plate. The contacts were counted as errors during the 10-day period, one group (the 'Yoga' group) received training in special physical postures (asanas), voluntary regulation of breaching (Pranayama), maintenance of silence, as well as visual focussing exercises (tratakas) and games to improve the attention span and memory. The other group (control) carried out their usual routine. After 10 days, the 'yoga' group showed a significant (Wilcoxon's paired signed-ranks test) decrease in errors, whereas the 'Control' group showed no change.

Certain postures such as that of a diver poised on the high board, immobile just before he springs into the air, require considerable muscular coordination even though the person is not actually mobile. The ability to maintain one's hand extended, yet steady is essential for a wide range of tasks.

Yoga is an ancient Indian tradition which through diverse physical and mental practices the practitioner strives to achieve a state of all around health. The practice of yoga has already been shown to be of therapeutic benefit in cases with psychosomatic ailments such as bronchial asthma (Nagarathna & Nagendra, 1985; Nagendra & Nagarathna, 1986). After 9 months of yogic practice, mentally retarded children also showed improvement in general mental ability, psychomotor coordination, and intelligent and social behaviour (Uma, Nagarathna, Nagendra, Vaidehi, & Seethalakshmi, 1989).

The present study was carried out with the aim of assessing whether Yogic training (for 10 days) would change the static motor performance in 45 school children as compared with an equal number of 'control' subjects, who did not practice Yoga but were also assessed after 10 days.

METHOD

Subjects

There were two groups, with 45 subjects in each, i.e., the 'Yoga' and the 'control' group. The 'Yoga' group had come to our research foundation in Bangalore to receive intensive training in Yoga for 10 days. Among the 45 there were 34 boys, and the group mean age was 11.3 (SD = 1.6 yr.). The 'control' group of students from a nearby school did not practice Yoga. In this group

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were 21 boys; the group's mean age was 12.0 (*SD = 1.0 yr.*). The design was explained to the subjects, and signed informed consent was taken from their guardians in accord with the ethical principles of the Indian Council of Medical Research, New, Delhi, India.

Testing procedure

Hand steadiness was tested using the simple apparatus conventionally employed (Hunt, 1936; Munn, 1946), which was fabricated by Anand Agencies, Pune, India. This apparatus consists of a metal plate in which are nine holes of graded diameters (the largest diameter being 8 mm and the smallest 2 mm). A metal stylus is connected to the plate in series, with a counter which is activated whenever the stylus makes contact with the metal plate. The subject is instructed to insert about 2 cm of the metal stylus in each hole, keeping his arm extended without support, and then maintain the stylus in the hole for 15 sec. without allowing the stylus to make contact with the side of the hole. Then the stylus is withdrawn also without making contact with the sides.

Subjects began the testing procedure with the largest hole first and then proceeded to the smallest one. The number of accidental contacts which the metal stylus made with the metal plate were registered on the electronic counter as the number of errors.

Design

Both groups ('Yoga' and 'control') were assessed initially on the test and again after 10 days. The groups' means were statistically compared using Wilcoxon's paired signed-ranks test. During the 10-day period the 'Yoga' group received training in Yoga whereas the 'control' group received no such training. This comparison was essential to ascertain whether merely repeating the exercise after 10 days would he enough to reduce the number of errors.

Training in Yoga

The 'Yoga' group received Yogic training for approximately 8 hours a day, which was aimed at all around (physical, mental, intellectual, and spiritual) development. The 10-day programme consisted of (1) Yogasanas, specialised physical postures which are meant to increase physical stamina and both physical and mental balance; (2) Pranayama or voluntary regulation and slowing of the breathing which is carried out to achieve a relaxed state of mind and to increase inner awareness; and (3) Kriyas, techniques which bring about cleansing of the internal organs (e.g., respiratory tract, abdominal muscles, and viscera). Among these, what was especially relevant to school children were eye-cleaning techniques (tratakas). The practice of tratakas involves concentration. For example, in some of the practices, the subject sits in a relaxed position, keeping the head straight. The arms are extended in different directions, with the gaze focussed on the tip of the index finger without moving the head. The periods of focussing are interrupted by periods of relaxation so that no visual strain is experienced.

In addition to these specialised practices, the training also included games to improve the attention span and memory as well as the telling of meaningful stories to foster a sense of values and feelings of responsibility.

RESULTS

The number of errors made at Test 1 were approximately similar for both groups. The group mean (± SEM) for the 'Yoga' group was 221.2 ± 10.0 (errors) and for the 'control' group 221.0 ±8.1 (errors). At the end of 10 days, the 'Yoga group' had 183.3 ± 7.1 (errors), and the difference between this and the initial value was statistically significant ($p<.01$, Wilcoxon paired signed-

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ranks test, two-tailed). The mean of the 'control' group on Test 2 was 217.8 ± 8.3; this difference was not significant on a similar test. These results suggest that 10 days training in Yoga can on immediate retest significantly show improved static motor performance. Our speculation is that learning and practising the different physical postures (asanas) could have improved voluntary control and eye-hand coordination. The special visual concentration exercise (tratakas) might have improved concentration so attention would vary less during the task. Since all Yogic practices have the ultimate goal of calming the mind, the over-all relaxation might have been beneficial. A subsequent follow-up would have been desirable, and other types of control groups could be explored.

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PRANAYAMA INCREASES GRIP STRENGTH WITHOUT LATERALIZED EFFECTS

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Abstract: The present study was conducted to determine whether breathing through a particular nostril has a lateralized effect on hand grip strength. 130 right hand dominant, school children between 11 and 18 yrs of age were randomly assigned to 5 groups. Each group had a specific yoga practice in addition to the regular program for a 10 day yoga camp. The practices were: (1) right, (2) left, (3) alternate- nostril breathing (4), breath awareness and (5) practice of mudras. Hand grip strength of both hands was assessed initially and at the end of 10 days for all 5 groups. The right, left- and alternate- nostril breathing groups had a significant increase in grip strength of both hands, ranging from 4.1% to 6.5%, at the end of the camp though without any lateralization effect. The breath awareness and mudra groups showed no change. Hence the present results suggest that yoga breathing through a particular nostril, or through alternate nostrils increases hand grip strength of both hands without lateralization.

Key words: *unilateral nostril breathing; hand grip strength; yoga: lateralization.*

INTRODUCTION

The nasal cycle is an ultradian rhythm characterized by alternating patency of the left and right nares, with a periodicity of two to eight hours (1). The two (right and left nostril patent) phases have been correlated with the activity and rest phases, respectively of the basic rest activity cycle (BRAC). It was described (2), how another primitive rhythm of "hunt (and eat) then rest" has also been coupled with the BRAC. At hunger contraction periods (the 'hunt - and eat' phase) the power of hand grip (tested with a grip dynamometer) is greater than at the quiescent or 'after dinner periods'. This suggested that the former phase correlates with the activity phase, while the latter correlates with the rest phase. There is no report regarding whether the hand grip can be correlated to the phase of the nasal cycle. However it was speculated (3) that right nostril breathing would increase the grip strength while left nostril breathing would have the reverse effect.

Certain yoga breathing practices which involve breathing exclusively through a single nostril, allow the effects of single nostril breathing to be checked, as these practices can be carried on effortlessly for prolonged periods.

In the present study the effects of these yoga breathing practices on hand grip were considered worth investigating based on the above mentioned facts as well as two more, viz., (i) unilateral forced nostril breathing has been reported to cause contralateral cerebral hemisphere stimulation (4), and [ii] it was shown (5) that difference in hand grip between the two hands are related to the relative functioning of the two cerebral hemispheres.

Hence the present study was designed to compare the effects of ten days of each of four yoga breathing practices, i.e. selective right nostril breathing, selective left nostril breathing, alternate nostril breathing, breath awareness without nostril manipulation, on the hand grip of both hands separately. It was aimed at finding out whether there was any lateralization effect (e.g. with right

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nostril breathing, right hand grip changes or whether a contralateral effect is observed). There was a fifth group which practised certain hand gestures (mudras). This was considered necessary as the pranayama practice in specific yoga exercises, i.e. sav, cav, and nds groups is associated with specific mudras. These practices involve keeping the fingers in specific postures, which could possibly influence hand grip strength.

METHODS

Subjects

The subjects were 130 school children of 11 and 18 years of age. They attended a 10 day residential yoga training camp during the school vacation. The children were all from a similar social and academic background. For all the subjects the right hand was dominant.

Design

The hand grip of both hands was assessed in all subjects, in the same manner. The subjects were then randomly assigned to five groups. All five groups had the same basic yoga training. In addition each of the five groups practised a specific yoga exercise, viz., [i] sav, surya anuloma viloma pranayama or right nostril breathing, [ii] cav, chandra anuloma viloma pranayama or left nostril breathing, [iii] nds,- nadisuddhi or alternate nostril breathing, [iv] baw or breath awareness without nostril manipulation, since breath awareness is a part of the first three practices, and [v] mdr with specific mudras. The first four groups had 30 subjects each, while the fifth group had 10 Subjects. The group average age (in years) ± SD for the five groups was as follows: sav - 14.1 ± 1.2, cav - 14.0 ± 1.1, nds 13.9 ± 1.2, baw 14.9 ± 1.8, and mdr- 14.4 ± 2.6. The assessments were made at the beginning and end of the 10 day camp.

Assessment procedure

Hand grip strength was assessed using a grip dynamometer (Anand Agencies, Pune, India). Subjects were tested in 6 trials, 3 for each hand alternately with 10 seconds gap between trials. During the assessment subjects were asked to keep their arm extended at shoulder level, horizontal to the ground as has been described earlier (6), The maximum value obtained during the three trials was used for analysis.

Yoga training

The subjects of all five groups practised asanas, pranayama practices (excluding the group-specific practices), meditation, lectures, and kriyas. Each of the specific practices have been described in detail elsewhere (7), and are mentioned briefly here. All five practices involved sitting cross legged with eyes closed. (i) Surya anuloma viloma pranayama (sav) involves inhalation and exhalation through the right nostril alone. (ii) Chandra anuloma viloma pranayama (cav) involves inhalation and exhalation through the left nostril alone. (iii) Nadisuddhi pranayama (nds) begins with exhalation (both nostrils) followed by inhalation through the left, then exhalation through the right nostril, inhalation again through the right, and exhalation through the left nostril, to complete the round. These specific pranayamas were practised as 27 rounds, four times a day. All 3 practices were accompanied by the practice of specific mudras or hand gestures. These have been described under the fifth group. (iv) Breath awareness or baw, involved being aware of the breath without manipulating the nostrils. (v) Mudra or mdr involved keeping the fingers in specific positions. For example, the right hand was used to manipulate the nostrils. The index and middle fingers were flexed, while other fingers were extended and used to gently close the nostrils. The left nostril with the ring finger and the right nostril with the thumb. The left hand was kept resting on the left knee with the tips of the thumb and index finger in contact and other fingers extended.

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Data analysis

The data obtained for each of the four groups at the beginning and end of the camp were compared with separate two tailed 't' - tests for paired data.

RESULTS

Right hand

There were significant increases in hand grip scores in the nds, sav, cav groups. The t and corresponding P values were: t = 3.19, P<.005; t = 2.69, P<.05; and t = 2.95, P<.01, respectively.

Left hand

There were significant increases in hand grip scores in the nds, sav, and cav groups. The 't' and corresponding P values were: t = 2.13, P<.05; t = 2.13, P<.05; t = 3.45, P<.002; and t = 2.31, P<.05, respectively. Group mean values ± SEM are provided in Table 1.

DISCUSSION

In the present study school children belonging to the alternate nostril breathing (nds), right nostril breathing (sav), and left nostril breathing (cav) groups showed a significant increase in the hand grip strength of both hands at the end of the ten day yoga training camp. The breath awareness (baw) and hand gesture / mudra (mdr) groups showed no significant change. There was no clear lateralization effect, i.e. neither ipsilateral nor contralateral to the nostril of breathing. Both SAV and CAV groups showed a marginally greater increase in left hand scores compared to the right hand (6.5% versus 4.4% and 5.3% versus 4.1%, respectively for sav and cav groups). The nds group showed marginally greater scores for the right hand (6.3 versus 5.0%).

The absence of change in the mdr group suggests that practice of the mudras alone did not change the hand grip strength. Also, breath awareness alone did not produce any change. This suggests that the practice of pranayama has a significant effect in increasing hand grip strength, bilaterally, irrespective of (i) the nostril through which the subjects breathe. (ii) maintaining breath awareness, or (iii) the practice of mudras.

Previous studies have shown that twelve weeks practice of selected asanas (30 min a day) cause a 21 percent increase in the hand grip strength in normal volunteers (6). The practice of

Table 1: Hand grip strength in kg in five groups at the start (S) and end (E) of the 10-day camp for right (RH) and left (LH) hands. Values are group mean + SEM.

		SAV	*CAV*	*NDS*	*BAW*	*MDR*
RH	S	25.6 ± 1.3	23.9 ± 1.0	24.0 ± 1.6	26.7 ± 1.4	29.5 ± 2.4
	E	26.7 ± 1.4*	24.9 ± 1.0**	26.4 ± 1.6***	27.1 ± 1.4	29.4 ± 2.2
LH	S	24.0 ± 1.3	22.3 ± 1.1	23.6 ± 1.7	25.1 ± 1.4	28.1 ± 2.2
	E	25.5 ± 1.3****	23.4 ± 0.9*	24.8 ± 1.5*	25.6 ± 1.4	28.2 ± 2.1

***P<.05, **P<.01, ***P<.005, ****P<.002, paired 't' test S versus E**

pranayama (48 min a day) in addition to physical workouts caused an increase in work rate on a treadmill and reduction in oxygen consumption per unit work, compared to a group which had

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physical workouts alone (8). Work did not increase blood lactate levels in the 'pranayama' group, which also had significantly lower values at rest. Hence the practice of pranayama made the significant difference, even though both groups were already doing physical workouts. This is similar to the results of the present study, in which the practice of pranayama four times a day in three groups (sav, cav, nds) made a significant difference to hand grip scores, compared to two other groups (baw, mdr), even though all five groups practised yogasanas, pranayama practices excluding the group-specific practices, kriyas, lectures and meditation. The availability of energy and oxidation of glucose is believed to influence the hand grip strength proportionately (9). Hence the pranayama practice may increase hand grip strength by reducing the oxygen requirement. The other important issue is whether *any* pranayama would cause the change, or whether the result was specific for sav, cav and nds practices. In the study cited above (8), the pranayama practice was not described. In the present study, since all five group practiced non-specific pranayamas and breathing techniques, i.e. sectional breathing, yoga breathing, nadisuddhi, brahmari, sitali, sitkari, sadanta and ujjayi, it appears as though the group specific practices (sav, cav, nds) made the difference. In the traditional texts pranayama practices involving manipulating the nostrils, are supposed to balance and awaken the life energy (10). This may be an explanation for the improved grip strength following sav, cav or nds. However, there is no scientific validation for this. It is also possible that the time spent in specific pranayama practices (27 rounds, four times a day), in addition to an hour a day for the non-specific practices (common to all five groups) was responsible, during the 10 day period. In the earlier cited study (8), subjects practised pranayama for 48 minutes a day, but they were followed up after one and two years. In order to be able to decide whether the effect observed in the present study is related to the duration or type of pranayama practice further comparative studies are required.

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Short Communication

PLASTICITY OF MOTOR CONTROL SYSTEMS DEMONSTRATED BY YOGA TRAINING

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Abstract: The static motor performance was tested in two groups with 20 subjects in each (age range 17 to 22 years, and 5 females in each group). Tests were carried out at the beginning and end of a 10 day period. The test required being able to insert and hold a metal stylus within holes of varying sizes for 15 sec. Accidental contacts between the stylus and the sides of the holes, were registered on a counter as errors. During the 10 days one group (the yoga group) practised asanas (physical postures), pranayama (voluntary regulation of breathing), meditation, devotional sessions, and tratakas (visual focussing exercises). The control group followed their usual routine. At the end of 10 days the yoga group showed a significant reduction in number of errors (Wilcoxon paired signed ranks test), while the control group did not change. Our earlier study showed a similar improvement in children (9 - 13 years). It was interesting to note the same degree of plasticity in motor control systems in young adults. The implications for rehabilitation programmes have been discussed.

Key words: *yogic practices, steadiness, motor control system, plasticity.*

INTRODUCTION

At the beginning of a race, athletes have to remain motionless, yet ready for activity. This static motor performance is essential for various activities.

We have already established (1), that after 10 days of training in yoga, school children (in the age range of 9-13 years), show considerable improvement in static motor performance, whereas a control group, which did not practise yoga, did not change.

The present study was carried out to determine whether this ability to improve after 10 days of yoga training, would also be seen in teenagers and young adults.

METHODS

Subjects

There were 2 groups with 20 college students in each. Their ages ranged from 17 to 22 years, with 5 females in each group. One group, i.e. the yoga group (mean age ± S.D. 18.2 ± 1.4 years) received 10 days training in yoga. During the 10 day period the 'control' group (mean age ± S.D. 17.9 ± 1.8 years) who were from the same college carried on with their usual routine. According to the ethical guidelines of the Indian Council of Medical Research, New Delhi, and the signed informed consent was taken from all the subjects.

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Testing procedure

Hand steadiness was tested with the conventionally used appartus (2). it was fabricated for us by Anand Agencies, Pune, India. This apparatus consists of a metal plate with nine holes of decreasing size. The largest being 8 mm in diameter, while the smallest is 2 mm in diameter. Subjects were asked to keep their arm extended without support, and insert a metal stylus to a depth of about 2cms in each hole, and maintain it there for 15sec, before withdrawing it. Accidental contact of the stylus with the sides of the plates are to be avoided. The stylus is connected to the plate in series, with an electronic counter which registers contacts between the stylus and the plate as errors.

Design of the study

The steadiness test was performed for both groups at the beginning, and again at the end of the 10 day period. The values were tested for significant difference using the non-parametric Wilcoxon paired signed ranks test (two tailed).

Yoga training

The 'Yoga' group had come to the Vivekananda Kendra Yoga Research Foundation, Bangalore, for a 10-day residential camp. The yogic practices took up approximately 8 hours each day, and consisted of asanas (physical postures), pranayama (voluntary regulation of breathing), meditation, devotional sessions, tratakas (visual focusing exercise to improve eyesight as well as concentration), and lectures on the theory and philosophy of yoga.

Table 1: Number of errors made during a steadiness test in 2 groups of subjects, initially and at the end of a 10 day period ("Final")

Group	Number of errors	
	Initial	Final
Control (n=20)	128.0 ± 8.0	128.5 ± 11.2
Yoga (n=20)	123.0 ± 4.2	100.9* ± 9.3

RESULTS

Both groups had approximately the same number of errors on the initial testing (Table 1). At the subsequent testing, 10 days later, the yoga group had a significantly lower number of errors ($P < 0.02$, Wilcoxon paired signed ranks test, two tailed), whereas the control group showed no change (Table 1).

DISCUSSION

The present study reports a 17.9% decrease in errors after yoga training suggestive of improved static motor performance. In our earlier study (1), we had found a similar decrease (17.1%) in errors made by school children after 10 days of yoga training.

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Also, our preliminary results (unpublished), on a group of 25 adults (which had no matched 'control' group), also revealed a 14% reduction in errors recorded by the steadiness test, after 14 days of yoga training.

This improvement in static motor performance can be attributed to better eye-hand co-ordination, improved fine motor control, concentration and also an overall state of well being and relaxation.

We have already reported (3), that 9 months of yogic practices improve the general mental ability, psychomotor co-ordination, and intelligent and social behaviour of mentally retarded children. The present results, though preliminary, suggest that considerable plasticity and scope for improvement in motor performance is still present in teenagers and young adults. This offers interesting scope for extending motor rehabilitation programmes to these age groups.

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FACTORS INFLUENCING CHANGES IN TWEEZER DEXTERITY SCORES FOLLOWING YOGA TRAINING

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Abstract : Yoga has already been shown to improve perceptual-motor skills, but the factors which influence its effects are not well defined. This study correlates age, gender, and motivation to learn yoga with the performance in a dexterity task following yoga. Tweezer dexterity was recorded in eighty subjects belonging to four groups. Two groups were given a month of yoga training. One group consisted of subjects who had volunteered to join for the training and the other group was deputed for the training as part of their job. The two remaining groups did not receive yoga training and were selected to match the respective groups receiving yoga, for age and sex, but not for their motivation to learn yoga. The test involved using a tweezer to place metal pins in evenly spaced holes in a metal plate within four minutes. Following yoga the scores of the volunteers who learnt yoga increased significantly, whereas there was no change in scores of deputed subjects and non-yoga groups. For reasons described in detail, factors such as age and gender did not appear to contribute to the difference in performance. Hence motivation to learn yoga appeared to influence the magnitude of increase.

Key words: *Tweezer dexterity; yoga; motivation.*

INTRODUCTION

The practice of yoga requires active participation of the subject. Hence the effect of factors such as the motivation to receive yoga training, as well as the subject's age and gender may be expected to influence the outcome. This is interesting to study as yoga training is increasingly being included as part of the routine program of various institutions ranging from schools (1) to jails (2), where subjects with different backgrounds and levels of interest in the program may participate.

The performance in perceptual-motor tasks requiring skill and attentiveness such as mirror star tracing (3) and hand steadiness (4, 5) was reported to improve following the practice of yoga. The present study compared scores in a dexterity task following yoga between two groups which differed with respect of their age, gender and motivation to learn yoga. Previous reports have shown that the performance in a peg moving task was stable between the third and fifth decade of life (6). Hence age differences may not be expected to contribute to baseline differences in performance in a motor task, though the correlation with performance after yoga has not been worked out. However gender does make a difference to dexterity, as a previous report (7) has shown that females have a higher baseline score on a dexterity task than males. The effect of gender on performance following yoga has also not been studied. Hence in the present study an attempt was made to understand the relative contribution of each of these factors (i.e., age, gender, and motivation to learn yoga) to the performance after yoga.

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METHODS

Subjects

There were four groups having twenty subjects each. Two groups consisted of (i) volunteers for yoga training (group average age 23.1±4.4 years; 10 male and 10 female subjects) and (ii) those deputed from their work place for training in yoga (group average age 32.5±4.1 years; all male subjects). Both groups practised yoga for a month. The other two groups consisted of corresponding age and gender matched subjects who were not given yoga training. These two control or non-yoga groups were not matched for motivation with the yoga groups. However, they did not appear to be specially motivated to learn yoga, as none of them asked for yoga training though the option of receiving training in yoga after the study was completed, was open to them.

Procedure

All four groups were assessed on a tweezer dexterity task detailed below, at the beginning and end of a month. The assessment was modelled on the O'Connor tweezer dexterity test (8). The apparatus was manufactured by Anand Agencies, Pune, India. Subjects were instructed to pick up cylindrical metal pins with a tweezer using the dominant hand and place them in holes in a metal plate, as quickly as possible. They were told when to begin the test and after 4 minutes were asked to stop. The number of pins placed was counted as the dexterity score. It was noted that all subjects were right hand dominant (for writing, throwing a ball, combing their hair etc.).

Data analysis

A two factor analysis of variance (ANOVA) was used to cheek for significant differences between the four groups, i.e., Factor A, and for difference between recordings on day 1 (before) and day 30 (after), i.e., Factor B. The Tukey test for the least significant difference between means was used for multiple comparisons.

A two factor analysis of variance (ANOVA) was used to test the gender effect, comparing the dexterity scores of three groups (Factor A), viz. the male volunteers (n=10), female volunteers (n=10) and the deputed subjects (all males, n=20). Their day 30 and day 1 data were compared (Factor B). Pairwise comparisons of the values of the three groups were made using the Student-Newman-Keuls method.

Yoga training

Both yoga groups (volunteers and deputed subjects) received 30 days training in asanas 90 min, pranayamas 60 min, kriyas 30 min, meditation 20 min, devotional sessions 60 min, guided relaxation 60 min and lectures on the theory and philosophy of yoga 60 min.

RESULTS

Two factor analysis of variance (ANOVA)

There was a significant difference between the four groups i.e., Factor A, $F=8.79$, $P<.001$. For Factor B (day 30 versus day 1), $F=10.41$, $P<.005$. The interaction between the factors (A x B) was also significant, $F=6.99$, $P<.001$.

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Tukey test for multiple comparisons between means

There were significant differences between dexterity scores of the volunteers for yoga training, recorded on day 1 ($q = 7.5$, $P<.001$). The day 30 values of these subjects were significantly different (i) compared to the day 30 values of the deputed subjects ($q=5.0$, $P<.005$) and (ii) compared to the day 30 values of their matched, 'non-yoga' group ($q=5.0$, $P<.005$).

Group averages values ± SEM are presented in Table 1.

Table 1: Tweezer dexterity scores in the four groups on day 1 and day 30. Values are group mean ± SEM.

	Day 1	*Day 30*
Volunteers	49.8 ± 2.3	65.4 ± 1.9*
Control	48.3 ± 1.9	48.1 ± 2.5
Deputed	49.6 ± 1.8	54.9 ± 2.2
Control	49.3 ± 2.3	47.6 ± 2.1

**P<0.001 (Tukey test) day 30 values compared with corresponding day 1.*

Separate two factor analysis of variance (ANOVA) specifically to study the gender effect

There was a statistically significant difference between the day 30 and day 1 values of the three groups ($F=29.8$, $DF=1.74$, $P<.001$). There was a marginally significant difference between the three groups, male volunteers (n=10), female volunteers (n=10) and deputed subjects (all males, n=20) [$F=3.11$, $DF=2.74$, $P=.05$]. All pairwise multiple comparisons by Student-Newman- Keuls method showed a significant ($P<.05$) difference between the day 30 values of deputed subjects compared to those of both male and female volunteers. The day 30 values of male and female volunteers were not significantly different. Both male and female volunteers showed significantly higher values on day 30 compared to their respective values on day 1.

Percentage changes and mean values are given in Table II.

TABLE II: Dexterity scores on day 30 after yoga of male volunteers, female volunteers and deputed subjects (all males). Values are group averages. The p value is for multiple comparisons, pairwise comparing Day 30 versus Day 1 of the respective group with Student-Newman-Keuls test.

Groups	Day 1	Day 30	% Change	P level
Male volunteers (n = 10)	48.1	66.3	37.8	<.05
Female volunteers (n = 10)	51.4	63.9	24.2	<.05
Deputed, all male (n = 20)	49.6	54.9	10.6	>.05 NS

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DISCUSSION

The present study showed that one month of yoga training increased tweezer dexterity scores significantly in volunteers but not in deputed subjects. A retest effect could be ruled out as the groups who did not practice yoga showed no change,.

Manual dexterity and the ability to perform rapid, fractionated movements depends on the presence of an opposable thumb (9) as well as on monosynaptic connections between the primary motor cortex and the ventral horn motor neurons in the cervical spinal cord (10). For example, in certain new-world primates where the corticospinal fibres end on neurons in Rexed's laminate of the intermediate zone, dexterity is markedly less.

Dexterous or skilled actions depend on the speed of gross movements of hand and arms, manual rhythm, and co-ordination of eye and finger control (11). The present study showed that the practice of yoga improved the performance in the tweezer dexterity task under assessment. An indirect correlation between high anxiety and poor performance in a motor task using a peg board was inferred by Stocker (12), who observed, a trend of least efficient motor performance correlated with high anxiety. Yoga practice for four to eight weeks has been shown to reduce symptoms and objective indicators of anxiety in patients with anxiety neurosis (13). Hence the anxiety-reducing effect of yoga may be responsible for the improvement in tweezer dexterity scores observed in the present study.

The difference in the response of the two groups who received yoga training could be related to three factors viz. (i) age, (ii) gender, and (iii) motivation.

The group average age of the volunteers for yoga training was 23.1 ± 4.4 years, whereas the average age of the deputed subjects was 32.5 ± 4.1 years. However there were four subjects who had exactly the same age in the two groups. The average percentage change among these four volunteers was 20.4%, whereas the four age matched, deputed subjects had an average percentage increase of 2.3%. Though there were only four age matched subjects among the two groups, these results suggest that the differences in age may not have contributed to the differences in performance between the two groups as the same trend was observed. Also, as described earlier, in a previous report the performance in a peg moving task was stable between the third and fifth decade of life (6). While the peg moving task was not same as the dexterity task used in the present study, the results of the peg moving study (6) may be extrapolated to support the conclusion that age differences were not responsible for the differences in performance between the volunteer and the deputed groups in the present study.

In the present study there was also no effect of gender on the dexterity scores after yoga, as the day 30 (after yoga) scores of the male and female volunteers were not significantly different. However the scores of both these groups were significantly higher than the day 30 scores of the deputed subjects, who were all males. These results suggest that gender differences did not influence the outcome.

The difference in motivation to learn yoga therefore remains the factor most likely to have influenced the performance of subjects in the dexterity task. It would have been preferable to have studied a non-yoga motivated group, but this was not possible in the present study. Further studies on groups receiving yoga training, in which motivation of each subject is rated and correlated with objective assessments, would help in understanding the contribution of this factor.

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YOGA TRAINING AND MOTOR SPEED BASED ON A FINGER TAPPING TASK

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Abstract : A finger tapping task was used to assess motor speed (MS) of both hands in 53 adults and, 152 children before and after yoga training and in 38 adults of a non-yoga (control) group. All subjects were right hand dominant. The 30 second tapping speed (TS) test was considered as three time intervals, i.e. 0-10 second (TSI), 10-20 seconds (TS2) and 20- 30 seconds (TS3). There was a significant (Student's t-test) increase in all three TS values following 10 days of yoga in children and 30 days of yoga in adults. However for both groups at baseline and final assessments, TS2 and TS3 were significantly lower than TS1. Hence the TS was increased after yoga training during the first 10 seconds of the test but not during the next 20 seconds. These results suggest an increase in motor speed for repetitive finger movements following yoga training, but not in strength or endurance, as the increase was not sustained over 30 sec.

Key words : *repetitive movernents; finger tapping; fatigue.*

INTRODUCTION

The frequency of successive, rapid alternating movements has been a standard measure to clinically evaluate one aspect of motor function, viz. motor speed (1) Finger tapping is one such example, where the number of taps in a given time is an index of the speed of motor activity. Motor speed has been shown to increase with age in childhood (2) while the reverse is true in adulthood, and males perform better than females (3) Speed of manual motor activity quite obviously varies with handedness, the dominant hand having a faster rate (4)

A comparison of right versus left hand motor speed is referred to as motor speed asymmetry (5) Unilateral motor speed appears to be more lateralized than various cognitive abilities, and there is believed to be a close association between right or left hand tapping speed and the activity of the left or right hemisphere respectively.

The present study aimed at assessing the effects of yoga training on finger tapping speed, with subjects categorized according to age and gender.

METHODS

Subjects

There were 91 adults (53 received yoga training, while 38 belonged to the control group). The control group had no experience of yoga, and were selected within the same age range as the yoga group to evaluate the effects of retest on motor speed. No other factors were considered. Matching of subjects individually was not possible, as there were different numbers of subjects in the two groups. The age range and group mean values ± SD of the two groups were as follows: experimental group (adults, yoga): 20-50 years, group average ± SD, 28.2 ± 7.6 years, control

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group (adults, non yoga): 20-50 years, group average ± SD, 29.9 ± 6.8 years. Assessments were also made in 152 children (group average age SD, 14.2 ± 1.3 years, 67 girls), who learned yoga. All the subjects were right hand dominant, based on standard questions (e.g. the hand used to write, comb, throw a ball).

Design of the study

Assessments on adult subjects were made at the beginning (initial) and end (final) of a 30 day period during which the yoga group (n=53) received training in yoga, while the control group (n=38) carried on with their routine activities. Assessments on the 152 children were carried out at the beginning (initial) and end (final) of 10 days of yoga.

Apparatus

The tapping board (Anand Agencies, Pune, India), consists of a wooden plank raised on one side by an angle of approximately 8° to the horizontal, providing an inclination on which the wrist could rest while tapping. Tapping would depress a metal bar, connected to a counter, so that each tap would increase the reading by '1'. The counter could be manually reset to zero.

Procedure

Subjects were asked to tap the metal bar as many times as possible during a period of 30 seconds. Assessments were made for both hands, the right was tested first followed by the left hand, with a gap of 10 seconds, in between. The number of taps was noted at the end of 10, 20 and 30 seconds, as the Tapping Speed, i.e., TSI, TS2 and TS3.

Training in Yoga

The yoga groups received yoga training for approximately 8 hours a day, which was aimed at all round (physical, mental, intellectual, and spiritual) development. The 10-day program for children and 30 day program for adults had certain similarities. These programs consisted of: (i) yogasanas, specialized physical postures which are meant to increase physical stamina and mental balance; (ii)) pranayama or voluntary regulation and slowing of the breathing which is carried out to achieve a relaxed state of mind and to increase inner awareness; (iii) kriyas, techniques which bring about cleansing of the eyes and internal organs (e.g., respiratory, tract, abdominal muscles, and some other viscera); and (iv) devotional sessions. In addition to these specialized practices, the training for children also included games to improve the attention span and memory as well as the telling of meaningful stories to foster a sense of values and feelings of responsibility.

Data analysis

The data were analysed in three ways: (a) The baseline changes in tapping speed from initial to final assessments were calculated comparing tapping speed in 0-10 seconds (TS1), 10-20 seconds (TS2) and 20- 30 seconds (TS3) on Day 1 and Day 30 (adults) and Day 1 and Day 10 (children) using Student's t-test. (b) To see the effect of time on tapping speed, the tapping speed between 20-30 seconds (TS3) and 0-10 seconds (TSI) of the same day were compared using Student's t-test. This was done separately for initial and final assessments. (c) The Motor Speed Asymmetry (MSA) was calculated, i.e. MSA = ([Right hand speed - Left hand speed]/[Right hand speed] ×100) (5). The MSA values at initial and final assessments were noted though they were not tested statistically for significant difference.

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RESULTS

Group mean values + SDs are provided in Table 1.

Baseline changes in tapping speed from initial to final assessments were calculated comparing tapping speed in between 0-10 seconds (TS1) 10-20 seconds (TS2) and 20- 30 seconds (TS3).

All adults of the yoga group showed significant increases in TS1, TS2 and TS3 of both hands after 30 days of yoga compared to before (Student's t-test). The percentage change and levels of significance are mentioned in Table II. Adults of both sexes belonging to the control group showed no change. Children of both sexes showed significant increases in all three groups (TS1, TS2 and TS3) of both hands at final assessments after 10 days of yoga, compared to initial assessments (Table II).

TABLE 1:

Tapping speed in subjects during 0-10 seconds (TSI), 10-20 seconds (TS2) and 20-30 seconds (TS3). Values are group means S.D.

				Initial			Final		
Subjects	*Sex*	*Category*	*Hand*	*TS1*	*TS2*	*TS3*	*TS1*	*TS2*	*TS3*
Adults	M	Yoga	R	43.2±9.2	41.8±8.2	41.2±8.9	51.1±9.5	47.0±7.8	45.7±9.7
(n=53)	(n=43)		L	40.1±8.8	37.0±8.6	35.2±8.6	47.1±9.8	42.9±7.9	40.3±9.4
	F	Yoga	R	37.8±9.3	34.8±7.3	31.9±6.0	52.5±9.3	42.9±7.9	40.3±9.4
	(n=10)		L	36.0±10.3	33.9±7.8	27.7±4.5	48.2±6.6	41.0±6.2	36.1±8.6
Adults	M	Control	R	51.7±7.5	48.6±8.6	47.4±1.9	53.9±6.9	50.2±8.4	47.1±8.0
(n=38)	(n=21)		L	48.8±7.9	43.9±6.9	39.1±9.8	51.1±8.2	45.4±6.4	36.6±6.4
	F	Control	R	38.4±7.4	38.2±7.9	32.1±8.0	38.3±9.6	37.6±9.3	30.4±8.4
	(n=17)		L	36.6±7.6	32.9±7.7	31.9±7.8	36.8±9.5	32.9±8.3	27.1±7.2
Children	M	Yoga	R	40.5±7.9	38.2±7.9	34.6±8.4	50.8±11	43.7±9.2	39.2±9.8
(n=152)	(n=85)		L	40.7±9.4	34.1±8.0	30.2±7.1	46.5±9.4	38.9±8.1	35.2±8.9
	F	Yoga	R	37.8±10.1	35.5±8.9	31.3±9.1	49.2±9.5	44.5±9.5	38.2±11.2
	(n=67)		L	37.3±8.2	31.7±7.1	27.4±6.4	44.9±9.9	38.3±10.2	33.1±8.4

Comparison of tapping speed between 20- 30 seconds (TS3) and 0-10 seconds (TSI)

At the initial assessment adults of the yoga group showed a significantly lower TS3 than TS1 of the left hand. After 30 days of yoga this difference was further enhanced (see Table II) and was also seen for the right hand TS (TS3 versus TS1). Adults of the control group showed a significantly lower TS3 than TS1 for the right hand initially, and for both hands at final assessment. Children showed significantly lower TS3 than TS1 for both hands at initial as well as final assessments (see Table II).

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TABLE II:

Comparisons of (1) initial and final values of tapping speeds in 0-10 seconds (TSI) 10-20 seconds (TS2) and 20-30 seconds (TS3) and (2) TS3 versus respective TS1 for initial and Final assessments

				Initial and Fianal			TS3 versus respective TS1	
Subjects	Sex	Categrory	Hand	TS1 %change	TS2 %change	TS3 %change	Percentagechange Initial	Final
Adults	M	Yoga	R	±18.7***	+12.5**	-10.7**	-10.6*	-4.2
(n=53)	n=43		L	+17.4**	+16.0**	14.6**	-14.4**	-12.3*
	F	Yoga	R	+33.9**	+34.4**	+35.7**	-15.6	-17.5*
	n=10		L	+38.9**	+20.9**	+30.3*	-23.0*	-25.1***
Adults	M	Control	R	+4.1	+3.3	-0.2	-8.3*	-12.6*
(n=38)	n=21		L	+4.5	+3.5	-6.3	-19.9	-28.3***
	F	Control	R	-0.3	-1.6	-5.2	-16.4	-20.6*
	n=10		L	+0.5	+0.1	+15.1	-12.8	-26.4**
Children	M	Yoga	R	+25.7***	+14.5***	+13.1**	-14.4***	-22.9***
(n=152)	n=85		L	+14.1***	+14.3***	+16.3***	-25.8***	-24.3***
	F	Control	R	-13.2***	+25.1***	+21.8***	-17.0***	-22.3***
	n=10		L	+20.2***	+20.6***	20.6***	-26.0***	-26.2***

Motor Speed Asymmetry (MSA)

MSA was calculated (based on a formula (5), MSA = [(Right hand speed-Left hand speed)/ Right hand speed × 100)]. For males of the yoga group MSA values at initial and final assessments were 10.9 and 9.3.

Females of the yoga group had initial MSA of 6.6 and final of 12.1. Males of the control group had MSA initial of 6.6 and final of 8.9. Females of the control group had 10.8 (initial) and 11.9 (final). For children the MSA values were 7.5 (initial) and 10.7 (final). A MSA value of 10 is expected in right-handed individuals, with values of 20 or more suggesting a greater than normal right hand advantage (6). Since all values were less than 20, they were within the expected range for right hand dominant persons.

DISCUSSION

There was a significant increase in baseline tapping speed (TS) between 0-10 seconds (TS1) 10-20 seconds (TS2) and 20-30 seconds (TS3) in both adults and children after 30 and 10 days of yoga respectively. However when TS between 20-30 seconds (TS3) and 0-10 seconds (TS1) was compared, all subjects of yoga and control groups showed a significant decrease in TS3 versus TS1, initially and finally. There is no clear pattern of change in motor speed asymmetry (MSA), hence the data were not analysed further. The increase in baseline TSI, TS2 and TS3, following yoga may be attributed to better motor co-ordination (7) either associated with, or independent of improved muscular efficiency following yoga (8). The absence of change in the

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control group helps to rule out a retest, or practice effect. There was no control group for the children who received yoga training, hence the retest effect was not ruled out.

At each trial, as subjects continued the task for 3 contiguous 10-seconds periods, the TS3 significantly reduced, suggesting a fatigue effect. Hence for this repetitive and continuous task, yoga practice did not reduce fatigue. This may also be related to the fact that in the first 10 seconds, after yoga training, subjects were significantly faster than in the first 10 seconds period before learning yoga. It is well known that an initial spurt of speed is difficult to sustain and results in fatigue. Strength typically refers to the capacity of the muscles to exert force under static conditions, though it can be measured under dynamic conditions also. It was found that slower movements usually result in higher levels of measured strength (9). Also in case of repetitive dynamic work, the combination of force and frequency of repetition determines the length of time that the activity can be endured. The present results suggest that in adults and children of both sexes, yoga practice for 30 and 10 days respectively, increases the initial speed of tapping, which does not persist during the last 20-seconds of a 30-seconds test. It is also interesting to understand whether this result is restricted to speed of finger movement, or if it affects gross activities which require repetitive responses, such as swimming and bicycling.

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EFFECT OF YOGA TRAINING ON MAZE LEARNING

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Abstract : The performance in a maze learning task was assessed in adults of either sex (n=31) before and after 30 days of yoga training and in an age and gender matched control group of subjects who did not receive training in yoga. Subjects were blind folded and used the dominant hand to trace the path in a wooden pencil maze. At each assessment, subjects were given 5 trials, without a gap between them. Performance was based on the time taken to complete the maze and the number of blind alleys taken. The time and error scores of Trial 1 were significantly less after yoga (two-factor ANOVA, Tukey test). Repeating trials significantly decreased time scores at Trial 5 versus Trial 1, for both groups on Day 1 and for the control group on Day 30. Hence the yoga group showed improved performance in maze tracing at retest 30 days later, which may be related to this group being faster learners and also the effect of yoga itself. Yoga training did not influence maze learning, based on the performance in 5 repeat trials.

Key words : *maze learning; yoga; performance.*

INTRODUCTION

Maze tracing is a task which gives data related to the highest levels of mental functioning, including the process of choosing, trying, and rejecting or adopting alternative courses of conduct or thought. Performance in this task improves with repetition (i.e., maze learning) (1). Maze tracing also has a motor component, which contributes to scores of the time taken to complete tracing the path(2).

Following yoga practice, volunteers were found to have improved static motor performance (3, 4) and manual dexterity (5). However, the effects of yoga practice on mental functions such as planning have not been studied.

The present study was designed to determine if yoga practice changes: (i) performance scores in a maze tracing task on retest after 30 days, and (ii) maze learning based on performance with 5 repeated trials.

METHODS

Subjects

There were two groups of 31 volunteers each, of either sex (16 males, 15 females), with group average age ± SD, 28.0 (± 8.9 years - yoga); (± 7.0 years - control). The yoga group attended a 1-month residential yoga training camp. The control group did not receive yoga training. All subjects were right hand dominant, based on questions about the hand used to throw a ball, look for change in a purse, and to write.

Design of the study

Assessments of both yoga and control groups were made on Day 1 and a month later (Day 30).

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Between assessments, the yoga group received yoga training, while the control group carried on with their routine activities.

Apparatus

The wooden pencil maze had two layers of wood. The bottom layer served as the base on which paper was kept, and the upper layer as the maze walls (Anand Agencies, Pune, India). A pencil tracing of the path that was approximately 1.2 cm wide could be obtained on the recording paper (6). There were 16 blind alleys of varying lengths and only one correct solution pathway.

Procedure

The maze was placed horizontally on a table, in front of the subject. The experimenter was seated across from the subject. Subjects were asked to trace the path in the wooden pencil maze with the dominant hand, while blindfolded and without lifting the pencil from the paper (7). The time taken to successfully complete the maze (in seconds) and number of errors, i.e., blind alleys taken, were noted. Each subject was given 5 trials, without a gap in between. Hence after completing one trial, the subjects hand was guided to bring the pencil to the starting point to begin the next trial. The time taken in seconds was noted using a stopwatch. The number of errors was noted after the experiment based on the pencil trace of the path on the paper. The scores (time and error) at Trial 1 gave the 'absolute' performance scores for maze tracing, whereas the difference between Trial 5 and Trial 1, gave an indication of the effect of repetition, related to maze learning.

Yoga practice

The yoga group received 30 days training in yoga postures (asanas, 90 min), voluntarily regulated breathing (pranayama, 60 min), yoga cleansing practices (kriyas, 30 min), meditation 20 min, devotional sessions 60 min, guided relaxation 60 min and lectures on the theory and philosophy of yoga for 60 min.

Data analysis

The data were analyzed using separate two factor analyses of variance for the two groups (yoga and control), with assessments (Day 1, Day 30) as Factor A and the 5 trials as Factor B. The Tukey test was used to test multiple comparisons for significant differences.

RESULTS

Group average time taken in seconds for the yoga and control groups at five trials on Days 1 and 30 are given in Fig. 1.

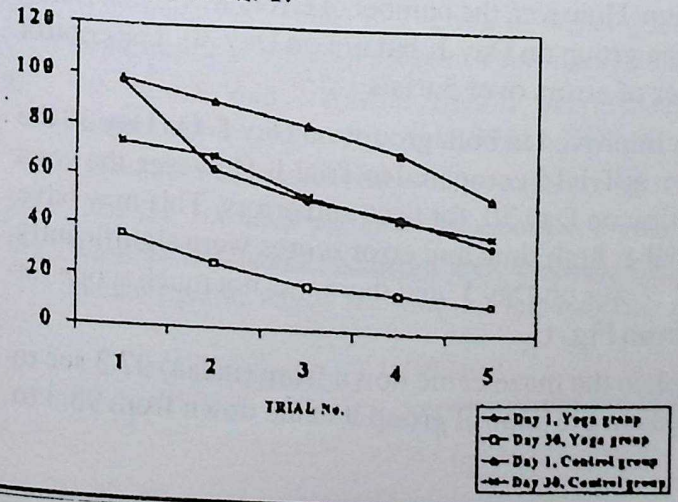

Fig.1: The group average time taken in seconds to complete the maze for yoga and control groups at each of five trials, on Day 1 and Day 30. Differences between the groups at baseline (Day 1, Trial 1) and over repeat trials can be seen.

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Two factor analysis of variance (ANOVA)

I) Time taken to complete the maze

The yoga group showed a significant difference between the assessments on Day 1 and Day 30, i.e., Factor A, $F = 110.46$, P<.001. There was a significant difference between the 5 trials, i.e., Factor B, $F = 17.06$, P<.001. The interaction between the factors (A x B) was also significant, $F = 3.01$, P<.05. The control group showed a significant difference in both cases between assessments on Day 1 and Day 30, i.e., Factor A, $F = 22.88$, P<.001, and Factor B (between trials), $F = 8.53$, P<.001.

II) Number of blind alleys (errors)

For the yoga group there was a significant difference between assessments on Day 1 and Day 30, i.e., Factor A, $F = 60.93$, P<.001, and for Factor B (between the 5 trials), $F = 6.04$, P<.001. The differences were not significant for the control group.

Tukey test for multiple comparisons between means

I) Trial 1 values on Day 30 compared to Day 1

The yoga group showed a significant decrease in time taken ($q = 10.63$, P<.001) and number of errors ($q = 6.50$, P<.001) at the end of 30 days, compared with Day 1.

II) Comparison of Trial 5 with the respective Trial 1

At the first assessment (Day 1), both yoga and control subjects showed a significant decrease in time taken for Trial 5 compared with Trial 1 (yoga group: $q = 10.84$, P< .001; control group: $q = 5.74$, P<.005). On Day 30, there was a significant difference in time taken between Trial 5 and Trial 1 for the control group ($q = 4.49$, P<.05). On Day 1 the yoga group showed a significant decrease in number of errors at Trial 5 compared to Trial 1 ($q = 6.16$, P<.001). As the standard table gives q values for 'v' at 120 and at ∞ but not at 300, values at ∞ have been considered (8). There was no significant difference in baseline values (Day 1, Trial 1) between groups.

DISCUSSION

The time taken to trace the maze and the number of errors were significantly decreased after 30 days of yoga practice, whereas the control group did not show this change. Over 5 trials both yoga and control groups showed a significant decrease in time taken to complete the maze on Day 1. On Day 30 the control group continued to show a significant decrease with repeated trials, which. was not observed in the yoga group. However, the number of errors was significantly less at Trial 5 compared to Trial 1, for the yoga group on Day 1, but not on Day 30. The control group did not show any differences in number of errors over 5 trials.

Maze learning based on time taken, was improved in both groups on Day 1. On Day 30 the control group showed a decrease in time taken at Trial 5 compared to Trial 1. However, the yoga group showed no significant effect of repetition on Day 30, for time and errors. This may have been related to the fact that on Day 30 at Trial 1, both time and error scores were significantly lower for the yoga group compared to Trial 1 scores on Day 1, and there was not much scope for further reduction. These trends are evident from Fig. 1.

Also, on Day 1, the time taken to complete the maze came down from (mean) 97.3 sec to 35.2 sec in 5 trials in the yoga group, whereas in the control group it came down from 98.3 to

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54.1 sec. Thus on Day 1 itself the yoga group had subjects who were fast learners, and therefore the two groups were not well matched for maze learning.

This decrease in time and error scores in the yoga group after 30 days of yoga practice compared with before may be related to this difference between the groups at baseline. At baseline the two groups did not take significantly different time to complete the maze. However, while the yoga group showed maze learning with reduced errors on Day 1, this change was not observed in the control group. This was another difference between the groups at baseline.

The effect of yoga on maze learning may also be related to factors such as motor performance, with improved motor performance seen as an increase in the speed of tracing the maze path. All subjects were right-hand dominant and used their right hand to trace the maze. Right hand activity in maze tracing involves more of left-hemispheric, abstract-conceptual strategy where the spatial configuration of the maze is learned as a series of left or right turns, with some interspersed up or down movements (9). In the present study, maze tracing may be believed to be carried out by left-right orientation. The decrease in time and error scores after yoga could also be related to better motor performance and improved left-right orientation, though baseline group differences prevent any definitive conclusion being made.

In summary, (1) The five trials on Day 1 and the five trials on Day 30 behave like 10 successive trials which lead to progressive improvement in both groups. (2) The yoga group has subjects who are fast learners compared to subjects in the control group. Hence the differences between the groups may be due to differences between the groups at baseline, rather than be the effect of yoga itself. To understand whether the effects of yoga training on maze learning observed in this study are related to baseline differences between groups, or to factors such as improved motor performance or left-right orientation, future studies may be planned with well matched groups and parameters selected to differentiate these contributing factors.

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Short Communication

IMPROVED PERFORMANCE IN THE TOWER OF LONDON TEST FOLLOWING YOGA

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Abstract: Twenty girls between 10 and 13 years of age, studying at a residential school were randomly assigned to two groups. One group practiced yoga for one hour fifteen minutes per day, 7 days a week, while the other group was given physical training for the same time. Time for planning and for execution and the number of moves required to complete the Tower of London task were assessed for both groups at the beginning and end of a month. These three assessments were separately tested in increasingly complex tasks requiring 2-moves, 4-moves and 5-moves. The pre-post data were compared using the Wilcoxon paired signed ranks test. The yoga group showed a significant reduction in planning time for both 2-moves and 4-moves tasks (53.9 and 59.1 percent respectively), execution time in both 4-moves and 5-moves tasks (63.7 and 60.3 percent respectively), and in the number of moves in the 4-moves tasks (20.9 percent). The physical training group showed no change. Hence yoga training for a month reduced the planning and execution time in simple (2-moves) as well as complex tasks (4,5-moves) and facilitated reaching the target with a smaller number of moves in a complex task (4-moves).

Key word: *Tower of London; Yoga; Physical training; Planning; Execution.*

INTRODUCTION

Studies on patients with various forms of brain damage have indicated that the ability to plan and sequence behavior in an orderly manner depends partly on the functioning of the pre-frontal cortex (1). The Tower of London test was developed to investigate planning abilities in patients with frontal lobe damage (2), though the test is now used to study planning ability in normal persons (3). In addition to planning strategy, the frontal association areas are needed for the execution of complex functions such as delayed response motor tasks and for changing strategies when required to do so (4).

The practice of yoga has been shown to facilitate mental functions such as visuospatial memory (5), and attention and concentration (6). The effect of yoga training has not been studied on planning. The present study aimed at assessing the performance in the Tower of London test, following yoga training. The study also aimed at assessing whether one or both of the two main components of yoga (i.e., increased physical activity and instructions to relax), would influence performance in this test, by comparing two groups, one of which practiced yoga, while the other had physical training, which consisted of increased physical activity without instructions to relax.

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METHOD

Subjects

The subjects were 20 girls, whose ages ranged between 10 & 13 years, who were selected at random from a total of 34 girls of the same age range studying in a residential school.

Design

The 20 subjects were randomly assigned to two groups using a standard random number table (7). One group was given training in yoga, which included physical activity, instructions to relax, and awareness of physical and other sensations. The comparison group was given physical training, so that this group would also have a comparable amount of physical activity as the yoga group, but without instructions about relaxation and awareness. Physical training and Yoga were practiced by the respective groups for one hour fifteen minutes per day, for 7 days a week. Both groups were assessed at the beginning and end of a month, during which they carried on their respective practices.

Assessment

The Tower of London test requires the subjects to move an array of colored beads mounted on three vertical rods, to match a particular goal arrangement (2). For each subject, increasingly complex goals were set, so that a subject had to complete three tasks, the first requiring 2 moves to reach the goal, the second 4 moves, and the third, 5 moves. Subjects were assessed based on planning time, execution time, and number of moves.

Yoga

The yoga training included physical postures (*asanas*), voluntarily regulated breathing (*pranayama*), internal cleansing practices (*kriyas*), meditation, devotional songs (*bhajans*) and relaxation techniques.

Physical training

Physical training consisted of standing and sitting exercises, jogging, bending forward, backward, and side ways, and lifting dumbbells.

Analysis

Post-pre comparisons of the data were made using Wilcoxon paired signed ranks test, for each group separately.

RESULTS

The group mean values (± SEM) of planning time, execution time, and number of moves, for both groups on Day 1 and Day 30 are given in Table I.

The yoga group showed a significant decrease in planning time for both 2-moves ($T = 3$, since $T_{.02(2),\,10} = 5$, hence $p < 0.02$) and 4-moves ($T = 1$, since $T_{.01(2),\,10} = 3$, hence $p < 0.01$); in execution time for both 4-moves ($T = 3$, hence $p < 0.02$) and 5-moves ($T = 0$, since $T_{.001(2),\,10} = 0$, hence $p < 0.001$), and in the number of moves in the 4-move task ($T = 1$, hence $p < 0.01$). The physical training group showed no change.

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Table 1

Effect of yoga on Tower of London Test as compared to that of physical training

		Yoga Group		Physical training Group	
		Day1 (mean ± SEM)	Day30 (mean ± SEM)	Day1 (mean ± SEM)	Day30 (mean ± SEM)
Planning time (In seconds)	2 moves	24.1 ± 1.2	11.1 ± 0.7*	19.3 ± 0.9	16.8 ± 0.9
	4 moves	47.4 ± 2.1	19.4 ± 0.9**	27.4 ± 1.1	23.3 ± 0.9
	5 moves	35.0 ± 1.6	32.1 ± 1.7	25.1 ± 1.2	22.9 ± 1.1
Execution time (In seconds)	2 moves	20.3 ± 1.2	17.5 ± 1.3	17.6 ± 0.9	28.9 ± 1.8
	4 moves	66.5 ± 2.2	24.1 ± 0.8*	51.9 ± 1.7	40.8 ± 1.5
	5 moves	94.0 ± 2.5	37.3 ± 1.3***	48.2 ± 1.5	66.5 ± 2.2
November of moves taken to complete in task	2 moves	7.4 ± 0.4	8.5 ± 0.8	7.8 ± 0.6	9.4 ± 0.7
	4 moves	17.2 ± 0.9	13.6 ± 0.5**	18.1 ± 0.8	16.0 ± 1.0
	5 moves	22.8 ± 0.9	20.2 ± 0.7	21.8 ± 1.0	21.6 ± 0.6

**p < 0.02, **p < 0.01, ***p<.001, Wilcoxon paired signed ranks test, comparing the Day 1 values with the Day 30 Values*

DISCUSSION

A month of yoga brought about maximum improvement in execution time. The planning time also improved significantly but in this respect the physical training group was already better at day 1 than the yoga group. That limits the validity of the finding although the improvement in the yoga group is statistically significant. Finally, the number of moves made to complete the task remained essentially unchanged in both groups. If in spite of no appreciable effect on number of moves, the execution time improved dramatically after yoga, it means that yoga improved alertness, as a result of which a wrong move was quickly perceived to be so and a fresh move made without much delay.

Early studies correlated poor performance in the Tower of London task with frontal lobe damage (2). More recently it has been shown, using single photon emission computerized tomography (SPECT) that the level of regional cerebral blood flow increased in the left pre-frontal cortex during the Tower of London task in normal persons (3). The improvement in the performance of the Tower of London task in the present study, following a month of yoga training suggests that yoga practice improves frontal lobe function.

A positron emission tomography study of regional cerebral metabolic responses showed that ratios of frontal versus occipital responses were significantly higher during meditation in eight meditators (8). A functional magnetic resonance imaging study (9), also showed that the dorsolateral prefrontal cortex is among other regions which are activated during meditation.

Hence meditation practice appears to involve the frontal regions. The present study suggests that practice of meditation and other components of yoga for a month improves planning, which is a frontal lobe function. This improvement may be related in some way to the fact that meditation increases frontal lobe activity evidenced by an increase in regional cerebral blood flow.

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YOGA BREATHING THROUGH A PARTICULAR NOSTRIL INCREASES SPATIAL MEMORY SCORES WITHOUT LATERALIZED EFFECTS[1]

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Summary- Uninostril breathing facilitates the performance on spatial and verbal cognitive tasks, said to be right and left brain functions, respectively. Since hemispheric memory functions are also known to be lateralized, the present study assessed the effects of uninostril breathing on the performance in verbal and spiritual memory tests. School children *(N= 108* whose ages ranged from 10 to 17 years) were randomly assigned to four groups. Each group practised a specific yoga breathing technique: (i) right nostril breathing, (ii) left nostril breathing, (iii) alternate nostril breathing, or (iv) breath awareness without manipulation of nostrils. These techniques were practised for 10 days. Verbal and spatial memory was assessed initially and after 10 days. An age-matched control group of 27 were similarly assessed. All 4 trained groups showed a significant increase in spatial test scores at retest, but the control group showed no change. Average increase in spatial memory scores for the trained groups was 84%. It appears yoga breathing increases spatial rather than verbal scores, without a lateralized effect.

The nasal cycle is an ultradian rhythm characterized by alternating patency of the left and right nostrils with a periodicity of 1 to 8 hours (Keuning, 1968). Some reports suggested a connection between the phases of the nasal cycle and the cerebral hemisphere which is dominant, mediated through a neural reflex (Werntz, Bickford, Bloom, & Shannahoff-Khalsa, 1983).

This was based on studies using the electroencephalogram (EEG). Forced unilateral nostril breaching modified EEG activity over the two hemispheres, with a greater amplitude on the side contralateral to the patent nostril. This was also believed to influence performance on specific tasks (Beubel, 1977; Klein, Pilon, Prossner, & Shannahoff-Khalsa, 1986; Jella & Shannahoff-Khalsa, 1993). In the report by Klein, *et al* (1986) adult volunteers tended to exhibit right-nostril dominance during normal breathing, to perform better on simple perceptual tasks with verbal information and known to be carried out by the left hemisphere, compared with subjects whose left nostril was dominant. Similarly during the left nostril-dominant phase subjects performed better on simple perceptual tasks using spatial information inferred to activate the right hemisphere. Both verbal and spatial tasks involved deciding whether stimulus pairs were same or different. For the verbal tasks stimuli were pairs of upper and lower case letters, while for the spatial task the stimuli were pairs of random seven dot patterns. There was no significant effect of forced uninostril breathing on performance of these tasks. In contrast, a subsequent study of undergraduate students whose group average age was 20.7 yr. (Jella & Shannahoff-Khalsa, 1993) showed that forced left-nostril breathing increased spatial performance on a cognitive task. This paper and

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pencil task tested mental rotation, manipulation and twisting of two-and three- dimensional stimulus objects; however, it did not validate that forced right-nostril breathing increased verbal performance on a task modeled after the Miller Analogies and SAT tests. Perhaps the difference in results obtained with normal breathing and with forced uninostril breathing may be related to forced uninostril breathing using an uncomfortable nose plug.

There are specific yoga breathing practices (pranayamas) which involve breathing selectively through a particular nostril. These techniques can be practiced effortlessly for prolonged periods and allow the effects of unilateral nostril breathing to be studied. The effects of three pranayama practices (which involve left nostril, right nostril, and alternate nostril breathing) on autonomic functions and metabolism have been reported to be similar to the effects of forced uninostril breathing (Shannahoff-Khalsa, 1991; Telles, Nagarathna, & Nagendra, 1994). The present study was carried out to assess whether practicing these three pranayama practices, i.e., left, right, or alternate nostril breathing pranayamas, or breath awareness four times a day for ten days would alter the performance of school children on verbal and spatial memory tests, compared to those of a control group who did no specific practice.

METHOD

Subjects

The subjects in the four trained groups were 108 school children whose ages ranged from 10 to 17 years and who were attending a 10-day residential yoga training course during their vacation. There was also a control group of 27 children who were matched with the other four groups on age and who were attending an English medium school. They were similarly assessed before and after 10 days during which they carried on with their routine activities. Hence, performance of this group primarily is pertinent to answering the question of whether an observed effect is merely a retest effect. All subjects were judged right-hand dominant, based on their self-reports as well as actual observation of the hand used by the subject to hold a pen while writing.

Design

The subjects were given the memory test on the first morning of the 10-day camp. The subjects were grouped by age; then subjects of a particu1ar age, e.g., 10 years, were randomly assigned to four training groups (ns = 27). Hence the four groups were of comparable average ages (see below). They had the same routine and learned the same yoga practices, with one difference. Each group was given a different pranayama technique to practice four times a day. The four techniques involved (i) breathing exclusively through the left nostril-chandra anuloma viloma (group's M age was 13.4, *SD* = 1.4 yr.), (ii) breathing exclusively through the right nostril surya anuloma viloma (group's average age was 14.0, *SD* = 1.5 yr.), (iii) breathing through both nostrils alternately-nadishudhi pranayama (group's M age was 13.8, *SD* = 1.2 yr.), or (iv) breath awareness without nostril manipulation (group's M age was 14.6, *SD* = 1.6 yr.). The fifth control group (group's M age was 13.6, *SD=0.9* yr.) of 27 children continued their routine activities for ten days.

Assessment

The subjects were told that the memory tests were for their self-assessment to understand the benefit they derived from the course. They were subsequently given a report, so they were enthusiastic and interested. They were not given further details about the study. The control group were also told that the tests were for their self-assessment and were also given a report.

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For both verbal the spatial tests a correct response was scored as 1/1 and an incorrect response as a practice trial showed that many subjects got a maximum score (with no scope for further change) when a free-recall test was used, so for the actual assessment a delayed recall test was used as this is known to be more difficult (Russell, 1979). However, there was no special interest in assessing the effect of interference on recall.

On both tests 20 subjects were assessed at a time while seated approximately a meter apart to avoid distraction. The test material was projected on a screen, allowing 10 sec. for each slide. After the 10 slides were shown, a mathematical problem (e.g., 7 minus 4 plus 9 minus 3 plus 6 minus 5 minus 8 plus 2) was projected on the screen: immediately after this, the subjects were asked to recall and write down (or in the case of spatial memory, to draw) within 60 sec. the 10 test items which had been shown to them.

To test verbal memory standard nonsense syllables of three letters, e.g., xol, were selected from a prepared list (Baddeley, 1993). Two different sets of 10 nonsense syllables were presented on Days 1 and 10. The test for spatial memory consisted of 10 simple line drawings. Geometrical or other shapes which could be described verbally, e.g., a square or a circle, were not used. The drawings were very simple and easy to reproduce. As described for verbal memory, there were two separate, similar sets of 10 line drawings each for Days 1 and 10.

Subjects were asked to make a note of which nostril was dominant, i.e., the phase of the nasal cycle, when completed the test. The subjects were asked to test this by occluding the nostrils, one at a time, to cheek which nostril was more congested and which was more easy to breathe through.

Pranayama Practices

The four separate pranayama practices given to each group were practiced as 27 rounds, four times a day (Nagendra, Mohan, & Shriram 1988). The four practices are described below.

(i) The surya anuloma viloma pranayama, or heat-generating breathing practice, involves breathing exclusively through the right nostril while the left nostril is gently occluded. (ii) Chandra anuloma viloma pranayama, or heat dissipating breathing practice, involves breathing through the left nostril whole the right nostril is occluded. (iii) Nadisudhi pranayama or cleansing-breathing practice requires the nostrils to be manipulated with the right hand so that breathing is alternately through left and right nostrils. During practices i, ii, and iii a cross-legged posture is assumed and awareness of the breath is maintained. During the fourth practice, i.e., (iv) Breath awareness, the subject maintained awareness of the breath without manipulation of nostrils.

Analysis

For both verbal and spatial memory tests a correct answer was scored as 1, whereas a wrong answer was scored 0. For each of the five groups separate two-factor analyses of variance were used to test for significance between the verbal and spatial memory test scores, between scores obtained on Days 10 and 1 and for the interaction of tests by days. Data of the 27 subjects in each group were used for analysis, hence there were 27 replicates.

The multiple-comparison Tukey test was used to assess the least significant difference in different comparisons of the groups means for each of the five groups, separately.

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RESULTS

The group means ± SDs of memory test scores obtained by all five groups for both verbal and spatial tests at initial and final assessments are given in Table 1. The F values given below were derived by linear interpolation from *df = 1,100* and 1,120 in the standard table, to get the F values for *df=1,104* (Zar, 1984). The two-factor analysis of variance showed a significant difference between the means for verbal and spatial memory test scores, i.e., Factor A for groups practicing the second and third pranayamas. For left nostril breathing $F_{1.104}$= 4.58 (*F*= 3.94 at *p* <.05, one-

Table 1 Means and standeard deviations of Memory scores of Five Groups (NS = 27) on verbal and spatial memory test for daily 1 and 10.

Group		Verbal Test Rating (Out of 10)		Spatial Test Rating (Out of 10)	
		Day 1	Day10	Day 1	Day 10
Right Nostril	M	3.8	4.6	3.1	5.9
	SD	2.2	2.1	1.7	2.0
Left Nostril	M	4.0	5.0	3.6	6.7
	SD	1.9	1.7	1.8	1.6
Both Nostrils	M	2.9	3.8	3.3	5.9
	SD	2.0	2.2	1.9	1.3
Breathing Awareness	M	3.4	4.4	3.1	5.6
	SD	2.1	1.8	1.6	1.8
Control	M	3.5	4.4	3.4	4.3
	SD	1.7	1.6	0.7	1.2

tailed), was significant as was the $F_{1,104}$ of 11.30 (F=9.60 at p<.005, two-tailed) for breathing with both nostrils. The difference between the tests was not significant for breathing with the right nostril, breath awareness, and the control group (PS >.05).

All four trained groups and the control group showed significant differences between values obtained on Day 10 and Day 1. For breathing with the right nostril $F_{1,104}$=21.48 (F = 12.88 at p < 001 , two-tailed) was significant as was the F of 33.43 for breathing with the left nostril, F of 21.76 for breathing with both nostrils, F of 23.32 for the breath awareness group, and F of 11.03 (F=9.60, two-tailed) for the control group.

Table 2: Comparisons of Difference Between means, q Values and Probabilities Based on Tukey Test for Verbal and Spatial Memory Scores for each of five Groups on Days 1 and 10

Comparisons		Differences	$q_{1.24}$	p
1. Spatial 10Vs Spatial 1	Group: Right Nostril	2.78	7.13	<0.001
2. Spatial 10Vs Spatial 1	Group: Left Nostril	3.07	8.77	<0.001
3. Spatial 10Vs Spatial 1	Group: Both Nostril	2.59	7.00	<0.001
4. Spatial 10Vs Spatial 1	Group: Breath awareness	2.48	6.89	<0.001
5. Spatial 10Vs Verbal 10	Group: Left Nostril	1.81	5.17	<0.001
6. Spatial 10Vs Verbal 1 0	Group: Bothe Nostril	2.11	5.70	<0.001

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The Tukey multiple-comparison test showed significant differences for (i) spatial scores on Day 10 versus spatial scores on Day 1 and (ii) spatial scores on Day 10 versus verbal scores on Day 10 (groups breathing with left and both nostrils). The comparisons, q values and levels of significance are given in Table 2.

DISCUSSION

The present study showed that after ten days of yoga breathing practices (pranayamas) all four trained groups showed a significant increase in spatial memory scores but not the control group. On the verbal memory scores each of the five groups showed no significant increase but relatively large standard deviations were noted. The percentage increase in scores suggested some differences. Blakeslee (1980) stated that the left hemisphere is more involved with verbal memory, while the right hemisphere is more involved with the recall of non-verbal, spatial information. It appears here that there was no specific lateralized effect of breathing through a particular nostril over the 10 days of pranayama practice by these children. The performance also did not appear to be related to the nostril which was patent at the time of testing.

Several factors could have contributed to the increase in spatial memory scores of the four trained groups. Children were enthusiastic about performing well on tile tests, which they had been told were a way of assessing the benefits they had obtained during the course, but this may have been less applicable for the control group as they received no special treatment. The positive effects of motivation on learning and memory scores increased in the trained groups, while verbal scores did not, makes it unlikely that increased motivation could have conuributed only to one set. Also, reduced anxiety can improve the performance on tasks requiring learning and memory (Saltz, 1970) and the anxiety-reducing effects of yoga practice, which are already known (Wallace, Benson, & Wilson, 1971) also could have facilitated this. The lack of higher spatial memory scores for the control group indicates that the increase was not due to familiar material given as a retest.

Although the scores on the verbal and spatial tests were not significantly different, on Day 1 and Day 10 means were significantly different for left and both nostril-breathing groups, so the practice of yoga improved delayed recall scores on the spatial task but not on the verbal task.

The absence of a lateralized effect of selective nostril breathing in the present study could be explained by different factors. Three previous studies reported lateralized effects of uninostril breathing on selective measures of hemisphere functions. The earliest report (Beubel, 1977) described relatively better verbal performance during both naturally occurring right nasal dominance and right forced uninostril breathing by practitioners of Kundalini yoga. In the study by Klein, et.al. (1986) naturally occurring shifts in the nasal patency were reported to be associated with modified performance on verbal or spatial tasks corresponding to the contralateral hemisphere. Both verbal and spatial tasks involved deciding whether stimulus pairs were same or different. For the verbal tasks stimuli were upper and lower case letter pairs, while for the spatial task the stimuli were pairs of random seven dot patterns. Forced unilateral-nostril breathing did not produce a change. In contrast, a subsequent study of undergraduate students whose group average age was 20.7 yr. (Jella & Shannahoff-Khalsa, 1993) showed that forced left- nostril breathing increased spatial performance on a cognitive task. This paper-and-pencil task tested mental rotation, manipulation, and twisting of two and three-dimensional stimulus objects. However, it did not confirm that forced right-nostril breathing increased verbal performance on a task modeled on the Miller- Analogies and SAT tests. Perhaps the difference between the results obtained with normal breathing and with forced uninostril breaching reflects that forced uninostril breathing

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using a nose plug may be uncomfortable. The present study indicated no lateralized effect following yoga breathing through a specific nostril. Assessments were made on Days 1 (before) and 10 (after) a period of practicing yoga breathing regularly. The 10 days may not have been adequate to produce lateralized changes in these children. Alternatively, the results suggest that the hemisphere-specific effect of selective nostril breathing might be immediate, measurable during or immediately after the selective nostril breathing. The effect was then not observed following regular practice for a specific period as in the present study. Further studies comparing the effect during or immediately after the practice with the effect over a period of time would make this point more clear, as might the application of sophisticated imaging techniques.

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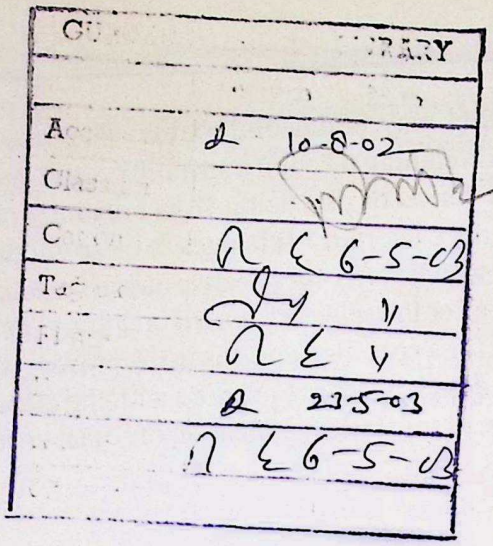

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What is VYASA?

VYASA is a Global Movement combing the best of the East (Yoga) with that of the West (Scientific Research) to bring Health, Harmony, and Happiness on Earth.

VYASA is the short form of Vivekananda Yoga Anusandhana Samsthana (Vivekananda Yoga Research Foundation). Since 1980 VYASA has grown under different names i.e. Swami Vivekananda Yoga Anusandhana Samsthana (sVYASA) from Feb 2000 to April 2002, Vivekananda Kendra Yoga Anusandhana Samsthana (VK YOGAS) from 1986 to 2000, and Vivekananda Kendra Yoga Chikitsa Tatha Anusandhana Samiti (VKYOCTAS) from 1981 to 1986.

What is Prashanti Kutiram?

The head quarters of VYASA is located in Prashanti Kutiram **(meaning Abode of Peace),** a spacious campus in the rural surroundings in Jigani Village, 20 miles from Bangalore off Bannerughatta-Anekal road (1 hour from Bangalore Air port). It consists of Arogya Dhama (Yoga Therapy Health Home), Indian Yoga Institute now grown as Vivekananda Yoga Maha Vidya Peetham, a Deemed to be University (or in short VYOMA) and Ashrama.

Objectives of VYASA

1. To bring the benefits of yoga to every one in the society and
2. To make yoga a socially relevant science by using the modern tool of scientific research

Main Activities of VYASA

1. Yoga for General Public
2. Yoga for unraveling the hidden dimensions of human potential
3. Yoga in Education for total Personality Development
4. Yoga Therapy for Modern Ailments
5. Yoga for corporate sector to deal with Stress and Management System.
6. Training in Yoga education - Certificate, Diploma, Bachelor, Masters & Doctoral courses in the Divisions of Yoga & Spirituality, Yoga & Life sciences, Yoga & Physical sciences, Yoga & Management studies & Yoga & Humanities.

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